before burning. Premix burners are now used for igniter service. The advent of forced draft fans and the need for increased burner capacity brought about the development of nozzle-mix gas burners. Nozzle-mix burners are capable of handling gas over a wide range of pressures depending on the design. Types of nozzle-mix burners include ring, gun, and multiple spud.
Figure 2-43 illustrates a register burner equipped with gas spuds nd an oil atomizer. Figure 2-44 illustrates a low excess air burner equipped with a gas ring. NFPA 85A, "Standard for Prevention of Furnace Explosions in Fuel Oil- and Natural Gas-Fired Single Burner Boilers-Furnaces," establishes requirements for safe operation of gas-fired boilers. Figures 2-49 and 2-50 show schematic arrangements of safety equipment for gas-fired fire tube and water tube boilers. "Standards for Natural Gas-Fired Multiple Burner Boilers" are found in NFPA 85B. For boilers rated less than 10,000 pounds of steam per hour, standards are set by Underwriters Laboratories Inc., Underwriters Laboratories of Canada, and other nationally recognized organizations.

2-24. LIQUEFIED PETROLEUM GAS.

Liquefied petroleum gas (LPG) is used for igniter service and occasionally as a standby fuel for natural gas- or oil-fired installations. LPG is a combination of propane and butane maintained in a liquid state through storage under pressure. NFPA Standards 58 and 54, Part 2 establish requirements for the storage and handling of LPG. For further information on LPG, refer to the Air Force Manual, No. 85-12.

SECTION IV. CONTROLS AND INSTRUMENTATION

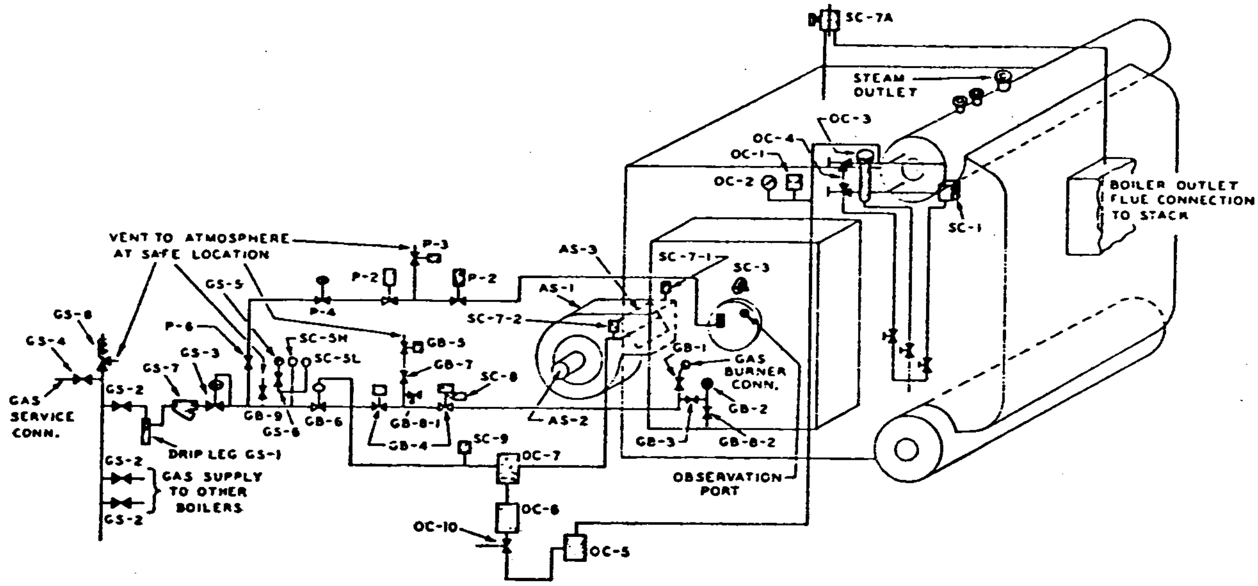
Controls and instrumentation are an integral and essential part of all central boiler plants. They serve to assure safe, economic and reliable operation of the equipment. They range from the simplest of manual devices to completely automated, microprocessor-based systems for control of boilers, turbines, and even end-users of energy. The subjects of controls and instrumentation are so intimately related that they are difficult to separate, and are discussed in parallel in the following chapter. Only those systems and items which are commonly used in central boiler plants are discussed.

2-25. FEEDWATER-DRUM LEVEL CONTROLS.

The importance of an adequate, properly controlled supply of feedwater to a boiler cannot be overemphasized. Boiler feedwater pumps and injectors (paragraph 2-38), low water fuel cutoffs (paragraph 2-27), and feedwater heaters (paragraph 2-37) are all part of an effective feedwater system. Steam boilers also require drum level controls to maintain the water level within limits established by the manufacturer. Operating with water levels that are too high may cause carryover of water from the drum, while opeating with levels that are too low can result in boiler tube failures due to insufficient cooling. Feedwater regulators are used to adjust the feedwater flow rate and maintain proper levels. Five types of feedwater regulators are commonly used: positive displacement, thermohydraulic, thermostatic, pneumatic level transmitter/cintroller, and electronic level transmitter/controller. Each is described below.

a. Positive Displacement. The positive-displacement type feedwater regulator (figure 2-51) is connected to the boiler drum or water column so that the average water level in the chamber is in line with that of the drum. The rise and fall of the float with the water level actuates a balanced feed valve through a suitable system of levers, and reduces or increases the flow of water to the boiler. The entire mechanism is in the pressure space and there are no stuffing boxes to leak or bind. The float is initially charged with a small amount of alcohol, which vaporizes and pressurizes in the float to counterct the boiler pressure exerted on the outside of the float. The valve and linkage are designed to give a gradual and continuous change in water flow between the high and low limits. This type of control will maintain a different water level for each steam flow produced by the boiler.

b. Thermohydraulic. Operation of the thermohydraulic or vapor-generator type of feedwater regulator (figure 2-52) depends upon the principle that steam occupies a greater volume than the water from which it was formed. The equipment consists of a generator, a diaphragm-operated valve, and the necessary connecting pipe and tubing. The central tube of the generator is connected to the boiler drum or water column, with the tube inclined so that the normal drum water level is slightly above the center of the generator. The generator, tubing and diaphragm chamber are filled with hot water. In operation, heat from steam in the upper portion of the inner tube raises the temperature of the water surrounding that portion of the tube and converts part of it to steam. This increases the pressure in the generator, forcing part of the water out of the generator until the water level is the same in both the inner and outer tubes. The water which is



NATURAL GAS FIRING ONLY

Typical Schematic Arrangement of Safety Equipment
Natural Gas-Fired Watertube Boiler with One (1) Burner
Automatic (recycling) or Automatic (nonrecycling) Controls

LEGEND

Gas Supply System:

- GS-1 Drip leg
- GS-2 Manual plug cock
- GS-3 Gas supply pressure reducing valve
- GS-4 Manual gas supply shut-off valve
- GS-5 Gas supply pressure gage
- GS-6 Gas supply pressure gage cock
- GS-7 Gas cleaner
- GS-8 Relief valve

Air System:

- AS-1 Forced draft fan
- AS-2 Forced draft fan motor
- AS-3 Forced draft fan control damper at inlet or outlet

Igniter (Pilot) System:

- P-2 Safety shut-off valves, auto. opening, spring closing (NC)
- P-3 Vent valve, auto. closing, spring opening (NO)
- P-4 Gas pressure regulating valve optional depending on igniter pressure requirements
- P-6 Manual plug cock

Gas Burner System:

- GB-1 Manual plug cock
- GB-2 Gas burner pressure gage
- GB-3 Gas burner pressure gage cock
- GB-4 Safety shut-off valves, auto. opening, spring closing (NC)
- GB-5 Vent valve, auto. closing, spring opening (NO)
- GB-6 Gas fuel control valve
- GB-7 Vent line manual plug cock (locked or sealed in open position)
- GB-8-1 Leakage test conn. upstream safety S.O. valve
- GB-8-2 Leakage test conn. downstream safety S.O. valve
- GB-9 Manual plug cock for venting high pressure from supply when required

Safety Controls: (All switches in "hot" ungrounded lines. See 4662)

- SC-1 Low water cut out integral with column or separate from water column
- SC-3 Flame scanner
- SC-5H Gas supply high pressure switch
- SC-5L Gas supply low pressure switch
- SC-7-1 Windbox pressure switch (note 2)
- SC-7-2 Fan damper position switch (note 2)
- SC-7A Purge A.F. switch (note 2)
- SC-8 Closed position interlock on GB-4
- SC-9 Light-off position interlock

Operating Controls & Instruments:

- OC-1 High steam pressure switch (note 1)
- OC-2 Steam drum pressure gage
- OC-3 Water column with high & low level alarms
- OC-4 Water gage and valves
- OC-5 Steam pressure controller
- OC-6 Manual auto. selector station
- OC-7 Combustion control drive unit or units
- OC-10 Modulating control low fire start positioner

NOTES: 1. With automatic (non-recycling) control on overpressure shutdown requires manual restart.
2. Purge airflow may be proved by providing either SC-7-1 and SC-7-2 (and similar devices for other dampers which are in series) or SC-7A.

FIGURE 2-50. SAFETY EQUIPMENT
GAS-FIRED WATER TUBE BOILER

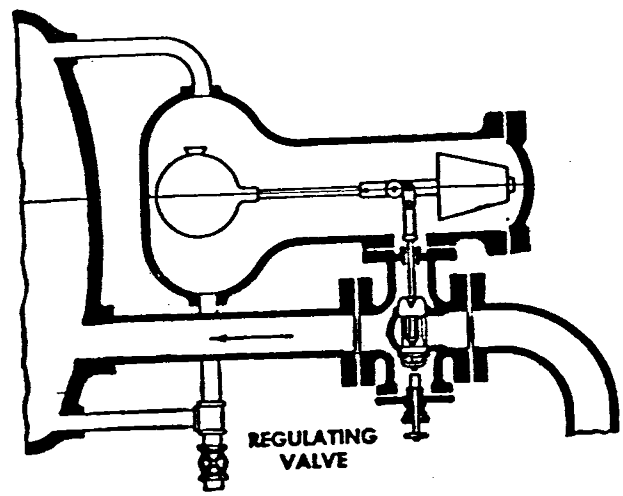


FIGURE 2-51. POSITIVE DISPLACEMENT
FEEDWATER REGULATOR

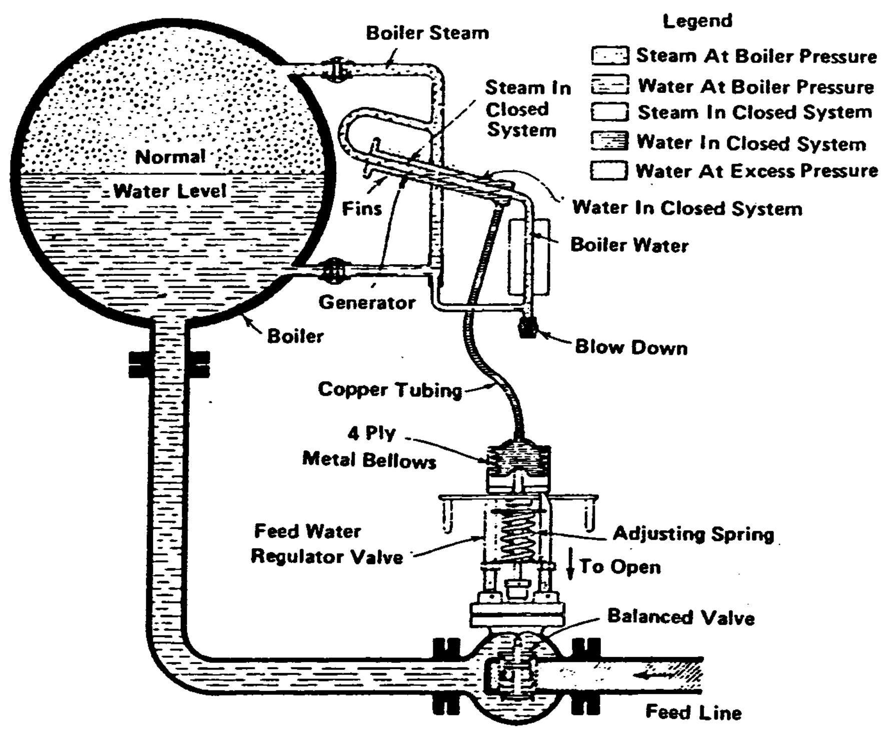


FIGURE 2-52. VAPOR-GENERATOR/THERMOHYDRAULIC FEEDWATER REGULATOR

forced out of the generator moves the diaphragm and opens the valve. When the water level in the boiler rises, some of the steam in the generator condenses and lowers the pressure. The spring on the valve forces water into the generator, closing the valve in the process. Fins are installed on the generator to radiate away some of the heat absorbed, thus preventing excessive pressures in the generator circuit nd increasing the speed of response of the regulator. This type of regulator establishes a relation between water level in the drum and the valve opening. Therefore, for each stream flow rate, a slightly different water level will be maintained. **c. Thermostatic.** Operation of the metal thermostat or expansion type of regulator (figure 2-53) depends upon the expansion and contraction of an inclined metal tube. The expansion tube is mounted on a steel frame in such a way that it is under constant tension. It is connected to the steam and water spaces of the boiler so that it contains only steam when the water is at its lowest level. The tube is then expanded to its maximum length. As the water level in the boiler rises, the water also rises in the tube, causing it to cool and contract. The tube is connected to a balanced valve in the feedwater line by a system of levers which move the valve as the tube length changes. The feedwater valve is at its maximum opening when the water level is low and the tube is filled with steam, and closes as the water level rises and the tube shortens. Note that all of the above regulators increase the flow of water as the level drops.

d. Pneumatic Transmitter/Controller. As boiler firing rates increased with the development of the modern water-cooled furnaces, the water storage capacity decreased and feedwater control became more difficult. A steam drum in a modern boiler can be emptied of water in minutes if the supplyis shut off. Changes in steam pressure result in expansion or swelling of the steam/water mixture and false water-level dindications. The mechanical controls discussed previously have limited capabilities and slow response times, and pneumatic controls were developed to provide more accurate drum level control. Basic to all pneumatic systems are a drum-level transmitter to sense level, a manual/automatic station to allow manual control during start-up, and a controller to determine the adjustment required to the feedwater valve. Siingle-, two- and three-element feedwater controls are available.

(1) **Single Element.** Single-element controls use a drum-level transmitter with a manual/automatic station and controller to send a signal to position the feedwater control valve. The controller can be adjusted to provide responsive and accurate control. Single element control is adequate for systems with gradual load changes.

(2) **Two Element.** In two-element controls, both drum level and steam flow levels are measured and used to control the feedwater (reference figure 2-54). Because steam flow is measured, this control system can sense and respond to load changes before they result in drum level changes. The system can thus compensate for swelling and shrinking in the boiler and drum which occur as the pressur changes during load swings. Two-element control is recommended for systems with frequent and large load changes.

(3) **Three Element.** Three-element controls sense feedwater flow in addition to drum level and steam flow. Three-element systems can compensate for changes in feedwater flow that may occur due to feedwater pressure or temperature change or feedwater valve inaccurcies. This level of control is not normally necessary except for very large boilers used in systems with large load changes, or in boilers producing superheated steam for use in a turbine.

e. Electronic Transmitter/Controller. One-, two-, and three-element feedwater control systems are also available utilizing electronic transmitters, manual/automatic stations, and controllers. Electric or pneumatic actuators can be used as final control drives for the feedwater control valve. An electro-pneumatic transducer is required to convert the electric signal into a pneumatic signal when pneumatic components.

2-26. COMBUSTION CONTROLS.

Combustion controls adjust fuel and air flows to satisfy boiler demand. Steam pressure, which changes with changes in demand, serves as the input signal by which the boiler firing rate is controlled. In hot water boilers, the water temperature leaving the boiler is used as the input signal. A combustion control system must maintain an efficient fuel/air ratio. For boilers equipped with induced draft fans or tall stacks, the combustion controls must also adjust fan inlet dampers or boiler outlet dampers to control furnce draft. A combustion control system, no matter how sophisticated, cannot do a better job of controlling a boiler than an operator. However, a combustion control system will operate continuously to make the necessary adjustments, while an operator has other responsibilities that prevent this kind of attention. Combustion controls systems are comprised of the following general types of components:

— Sensing elements
— Transmitters
— Controllers
— Indicators
— Actuators
— Control drives
— Control valves
— Dampers

These components may be combined in an endless variety of arrangements to provide almost any degree of sophistication required.

a. Control Concepts. Open-loop and closed-loop control are both used in the boiler plant. Open-loopo control (also called "feed-forward") takes an input-demand signal and generates a single output in response to the demand. The

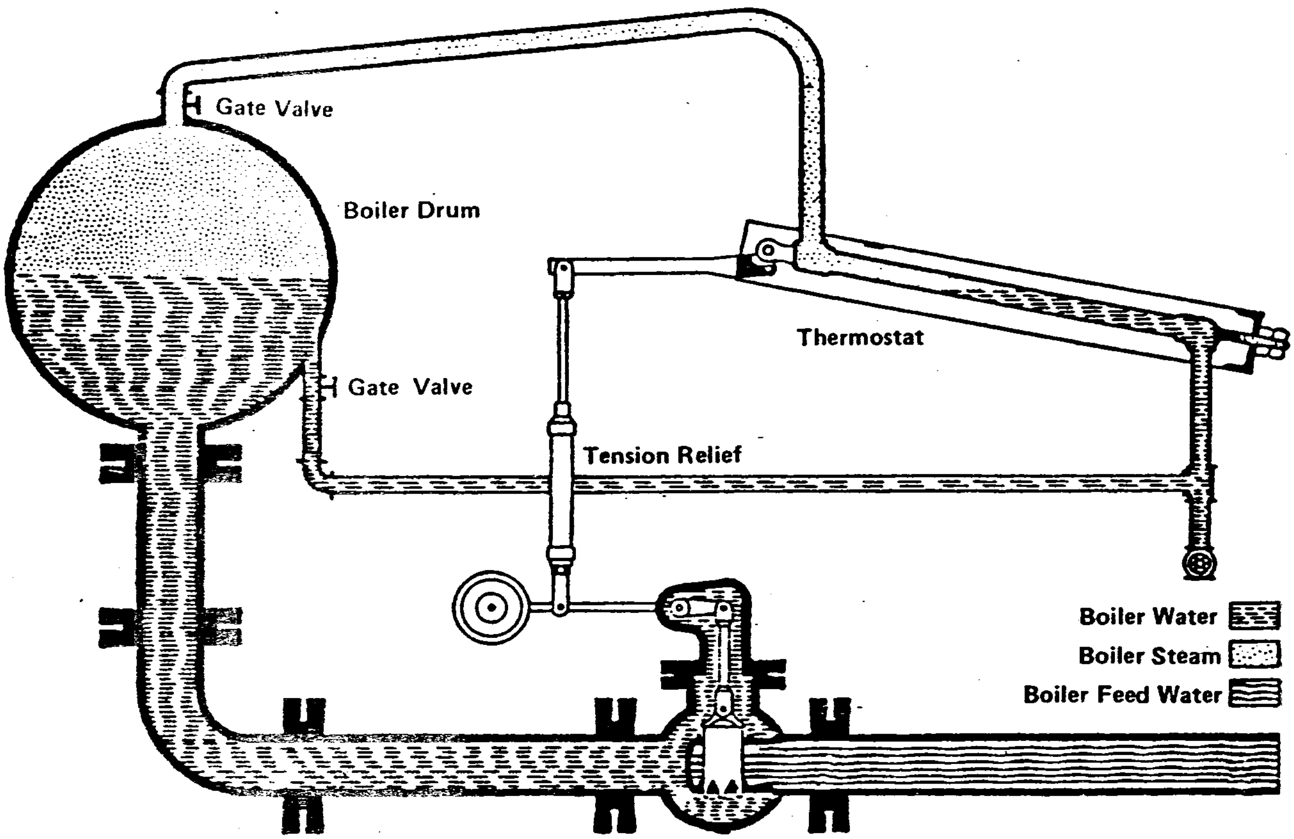


FIGURE 2-53. THERMOSTATIC/METAL EXPANSION FEEDWATER REGULATOR

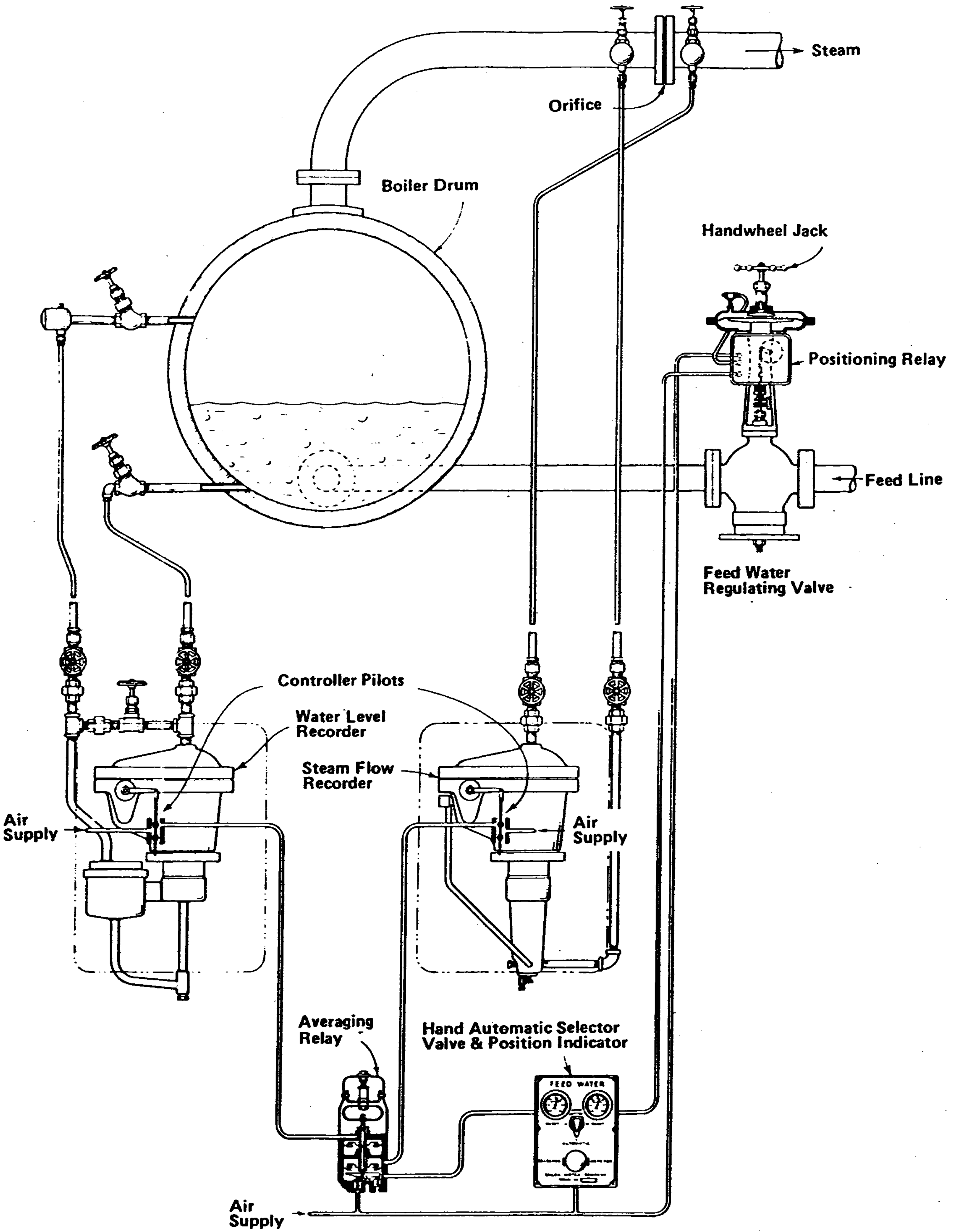


FIGURE 2-54. TWO ELEMENT FEEDWATER CONTROLS

result of the control action is not considered. Closed-loop (or "feedback") control monitors a system variable and automatically generates an output to adjust the system. If the system remains out of balance, the control will continue to change its output until the desired result is obtained. A simple pneumatic actuator on a valve is an example of open-loop control (reference figure 2-55). The actuator receives a signal and generates an output, the movement of its shaft. This same poneumatic actuator could be converted to closed-loop control by equipping it with a positioner (reference figure 2-56). The actuator receives a signal and generates an output to move the shaft. The shaft position is measured as feedback. If the shaft is not in the desired position, the output from the positioner is automatically readjusted, and the shaft is moved again until it is in the correct position. A basic advantage of closed-loop control is that it provides more accuracy of adjustment due to its ability to overcome hysteresis losses. Hysteresis losses are caused by friction in lilnkages, valves, actuators, and other mechanical items. The effect of hysteresis is to cause a valve or mechanism to stop at a slightly different adjustment each time. A typical open-loop control may be able to control position wo within plus or minus 5% of a desired setting, whereas a closed-loop control can typically control to approximately plus or minus 1%. Closed-loop control is available as one-, two-, or three-mode control using proportional, integral, or derivative responses. These different responses are discussed below.

(1) **Proportional.** Proportional control (also called gain control) is the simplest form of closed-loop control. In proportional control, the fifference between a setpoint and a system variable is measured, and corrective action is taken by adjusting the control output. A proportional steam pressure control system is illustrated in figure 2-57. Steam pressure setpoint and actual steam pressure are compared, and an output is generated in proportion to the difference. Figure 2-58 illustrates proportional control. For a proportional gain setting of 5, the fuel valve is opened 5% for each 1% drop in steam pressure. Proportional gain, or simply gain, is defined as "the control output change, in percent, divided by the system variable change, in percent."

$$\text{Gain} = \frac{\text{Change in Control Output,\%}}{\text{Change in System Variable, \%}}$$

Proportional band is the inverse of gain, expressed in percent.

$$\text{Proportional} = \frac{1}{\text{Gain}} \times 100 = \frac{\text{Change in System Variable,\%}}{\text{Change in Control Output, \%}} \times 100$$

Thus, a gain of 5 is equivalent to a proportional band of 20. Figure 2-59 illustrates the response of a steam pressure control system to a change in steam flow. Note that offset or deadband is the difference between setpoint and steam pressure. The following observations should be noted about proportional control:

(a) Proportional control operates and establishes steady-state positions because a difference exists between the setpoint and the system variable. In the example shown in figure 2-58, only at the 50% fuel valve position would steam pressure exactly match the setpoint. At all other fuel valve positions, a difference of up to 10 psi from setpoint would be required to maintain the fuel valve position which would satisfy a steam flow demand.

(b) The larger the gain (or the smaller the proportional band) of a control, the greater the response of the control to changes in the system variable, and the smaller the deadband.

(c) The smaller the gain (or the larger the proportional band), the smaller the response to changes in the system variable, and the larger the deadband.

(d) A large gain may not be stable. A fuel valve cycling between full open and full closed is an example of unstable operation.

(2) **Integral.** Integral (also called reset) control was developed to improve the accuracy of proportional control. Integral action works to eliminate the deadband which is inherent in proportional control. Integral control adjusts the control output in steps based upon the offset and the time the offset has existed. Adjustment continues until the setpoint and the system variable are the same or until maximum orminimum output is reached. Figure 2-60 illustrates proportional plus integral control response to a change in steam flow. Proportional plus integral control is also called two-mode control. Reducing the integral time increases the integral control response, while increasing the integral time reduces the control response.

(3) **Derivative.** Derivative is a mathematical term that considers the rate of change. In some systems, derivative (or rate) response can improve the speed and accuracy of the control by anticipating a trend before an actual change occurs. Proportional plus integral plus derivative control is called three-mode control; it is rarely used in a steam heating plant but can be very effective in a hot water plant by recognizing change in direction of a system variable. For example, when boiler outlet water temperature starts to fall after having been rising, the fuel valve should be opened to supply heat to satisfy the new demand for hot water, even though the setpoint may not have been reached yet. Reducing the derivative time increases the derivative control response, while increasing the derivative time decreases the response. To much derivative control can dampen other control responses.

b. Pneumatic Control Basics. A basic pneumatic controller is shown in figure 2-61. The controller consists of the five

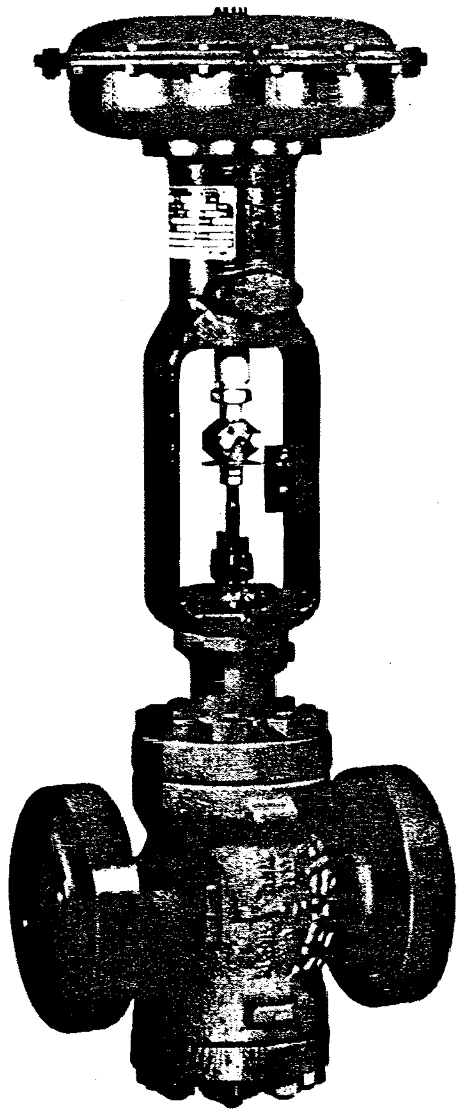


FIGURE 2-55. CONTROL VALVE WITH PNEUMATIC ACTUATOR

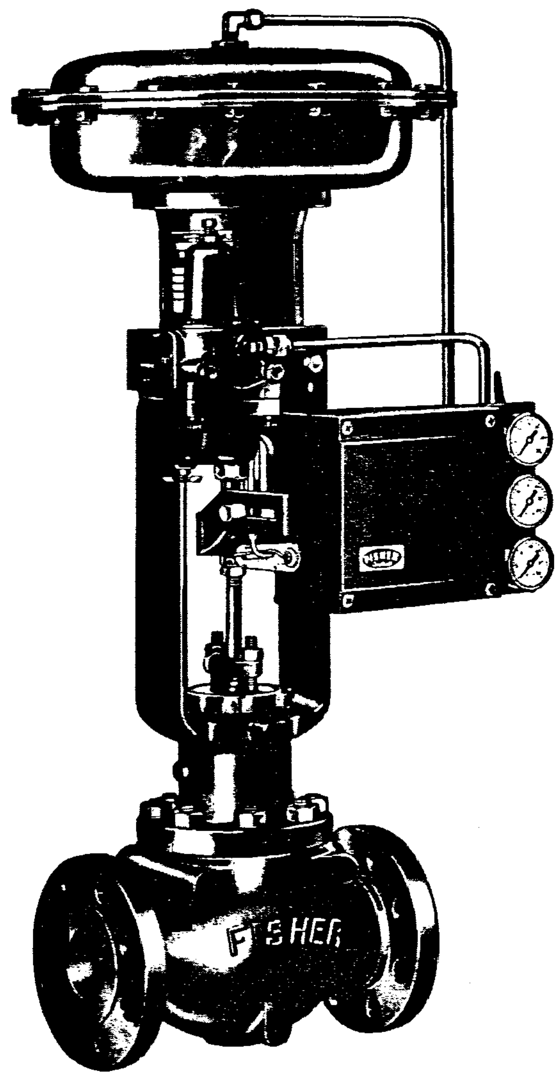


FIGURE 2-56. CONTROL VALVE WITH PNEUMATIC ACTUATOR AND POSITIONER

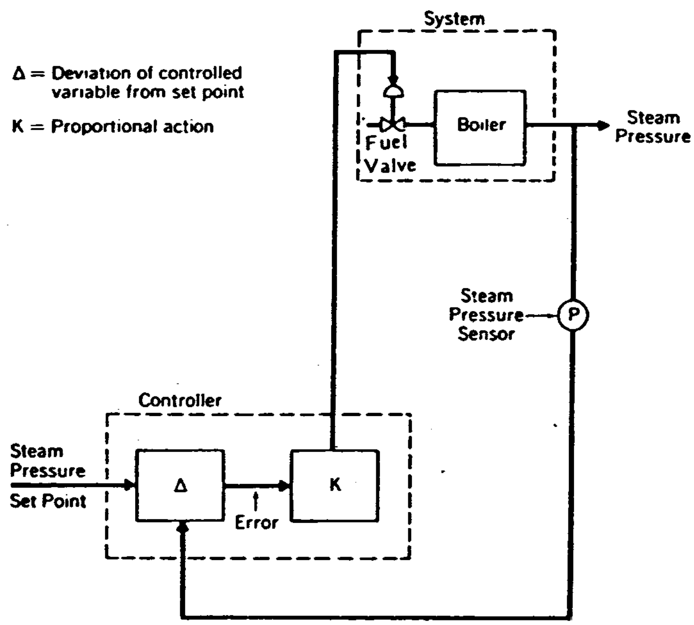


FIGURE 2-57. STEAM PRESSURE CONTROL SYSTEM

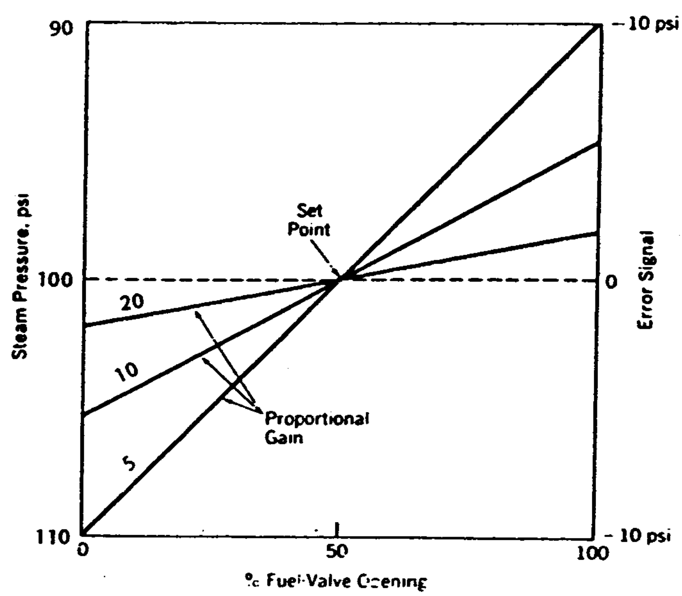
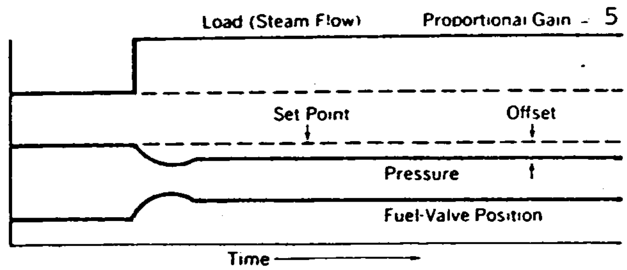


FIGURE 2-58. PROPORTIONAL CONTROL



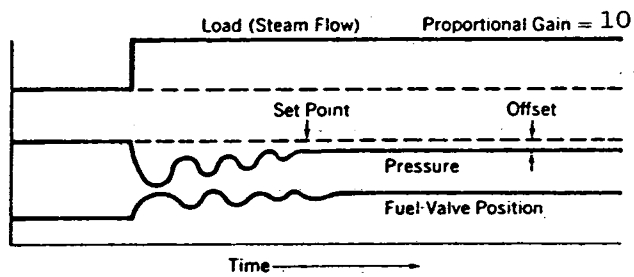


FIGURE 2-59. PROPORTIONAL RESPONSE

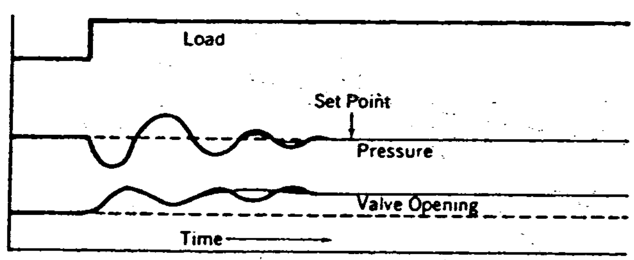


FIGURE 2-60. PROPORTIONAL PLUS INTEGRAL RESPONSE

basic components listed below.

— Measuring element.
— Flapper
— Nozzle or venting orifice
— Restrictive or input orifice
— Chamber between the orifices

The flapper is situated so that it can shut off or throttle the flow of air out of the nozzle orifice, and is moved by the sensing element in response to a change in the controlled variable. The flapper and venting orifice are often considered as one unit, called a vent valve. Instrument quality air is supplied to the controller through the input orifice and is vented to the atmosphere through the venting orifice, as long as the flapper is positioned away from this orifice. The venting orifice is larger than the input orifice; therefore, if the flapper restricts the flow of air, air pressure in the chamber and control air pressure to the final control drive positioner both increase. The mount of clearance between the flapper nd the nozzle controls the air pressure fed to the control drive. The measuring element controls the flapper-nozzle clearance as dictated by the pressure, temperature, flow level, etc., being controlled. This fundamental controller has rather limited capability and, if used, must be situated close to the device it controls. It ıust actuate a control requiring only a small volume of ⌣ir, and it must control a process that requires only a limited control range. It is a one-mode controller, with the proportional band determined by the position of the pivot point, venting orifice, and measuring element. Two-mode and three-mode controllers are developed by using additional measuring elements, flappers, orifices, chambers, adjusting mechanisms, and springs. The basic controller is flexible if equipped with a power or volume booster relay. A typical two-dddiaphragm booster relay is shown in figure 2-62. The ratio of the two-diaphragm areas may be varied to suit the desired input-output ratio. A relay with a three-to-one diaphragm ratio will give a 3-psi change in the control air output signal for each 1-psi change in chamber "A". Depending upon the ratio of the diaphragm areas, this type of relay may be used to increase either the volume of air or the control air pressure at the drive. Control air from the controller chamber, acting on the diaphragm in chamber A causes diaphragms "A" and "B" to move downward, thus opening valve 2 which admits air from chamber "D" to chamber "C." When the force exerted by the control air in chamber "C" equals the force in chamber "A", the downward movement of the diaphragm assembly ceases and the control air output pressure to the control device will remain constant. When the pressure in chamber "A decreases, the diaphragm assembly will move upward; valve 2 will lose and valve 1 will open, thus venting air out of chamber "C" to the atmosphere through chamber "B". This causes a decrease of control air pressure to the control device.

c. Controls for Stoker-Fired Boilers. Combustion controls for stoker-fired boilers must have the ability to adjust the fuel/air ratio to compensate for changes in coal heating values, moisture, bed thickness, forced draft fan performance, and ambient air changes. Spreader stokers, which burn a portion of the coal in suspension, react differntly than underfeed, traveling, chain, and vibrating stokers. Spreader stokers respond best to a change in fuel feed rate, while grate-burning stokers respond well to changes in air flow rates. Two types of control, paralled positioning control and series/parallel control, are commonly used with stokers.

(1) **Parallel Positioning Control.** Figure 2-63 illustrates a parallel positioning control system. A deviation of steam pressur from setpoint results in the master controller signaling the fuel actuator and the combustion and overfire air actuators to reposition themselves to a higher firing rate. Two fuel/air ratio control stations are provided to allow the operator to adjust and trim the combustion and overfire air supply. A furnace pressure controller monitors the furnace pressure and adjusts the ID fan inlet damper to maintain a slightly negative pressure in the furnace. Manual/automatic stations are provided to allow manual control.

(2) **Series/Parallel Control.** Figure 2-64 illustrates the series/parallel system. In this system, steam pressure is used to control the fuel feed rate and steam flow to control the air flow rate. A combination air-flow and steam-flow meter is discussed in paragraph 2-28. Operators use this type of meter as a guide to control the relationship between air **required** to burn the fuel and air **actually supplied.** The steam generation rate is used as a measure of air required, while the flow of gases through the boiler setting is used as a measure of air supplied. By comparing the two, a check on the air to fuel ratio in the furnace can be obtained. This type of lmeter has been in use for lmany years and is commonly called a "boiler meter". The series/parallel control combines poositioning control for the fuel with metering control for the air flow. Initial calibration and repeatability of the air flow signal are very important. Overfire air fans are also modulated with boiler load to obtain best combustion results at the lowest possible excess air levels. Although this feature has not been shown in figure 2-64, it would be provided for many applications.

d. Controls for Oil- and Gas-Fired Boilers. Parallel positioning and parallel metering type combustion controls are available for oil- and gas-fired boilers. Either type may be equipped with trimming control to adjust the fuel/air ratio based upon the oxygen level in the flue gas. Pneumatic, electric, electronic and compouter-operated controls are available.

(1) **Parallel Positioning Control.** With the compactness of modern oil and gas burner packages, it is possible to use a single set of jackshaft and levers to control both fuel and air. Figure 2-65 illustrates a typical jackshaft system.

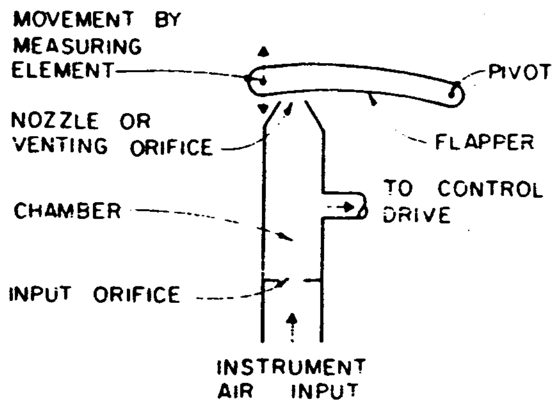


FIGURE 2-61. BASIC PNEUMATIC CONTROLLER

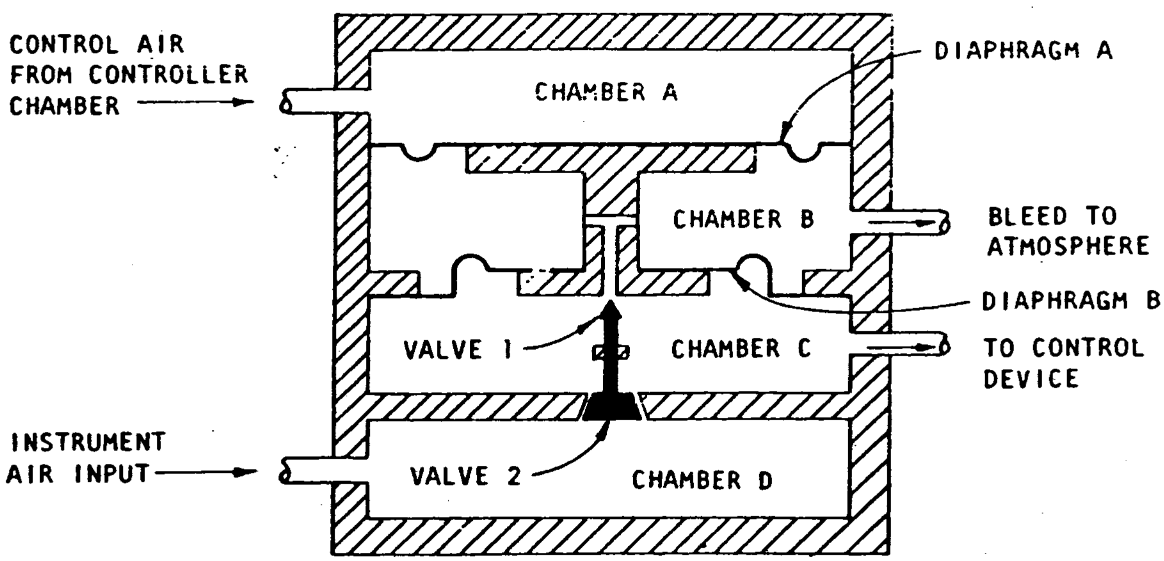


FIGURE 2-62. PNEUMATIC BOOSTER RELAY

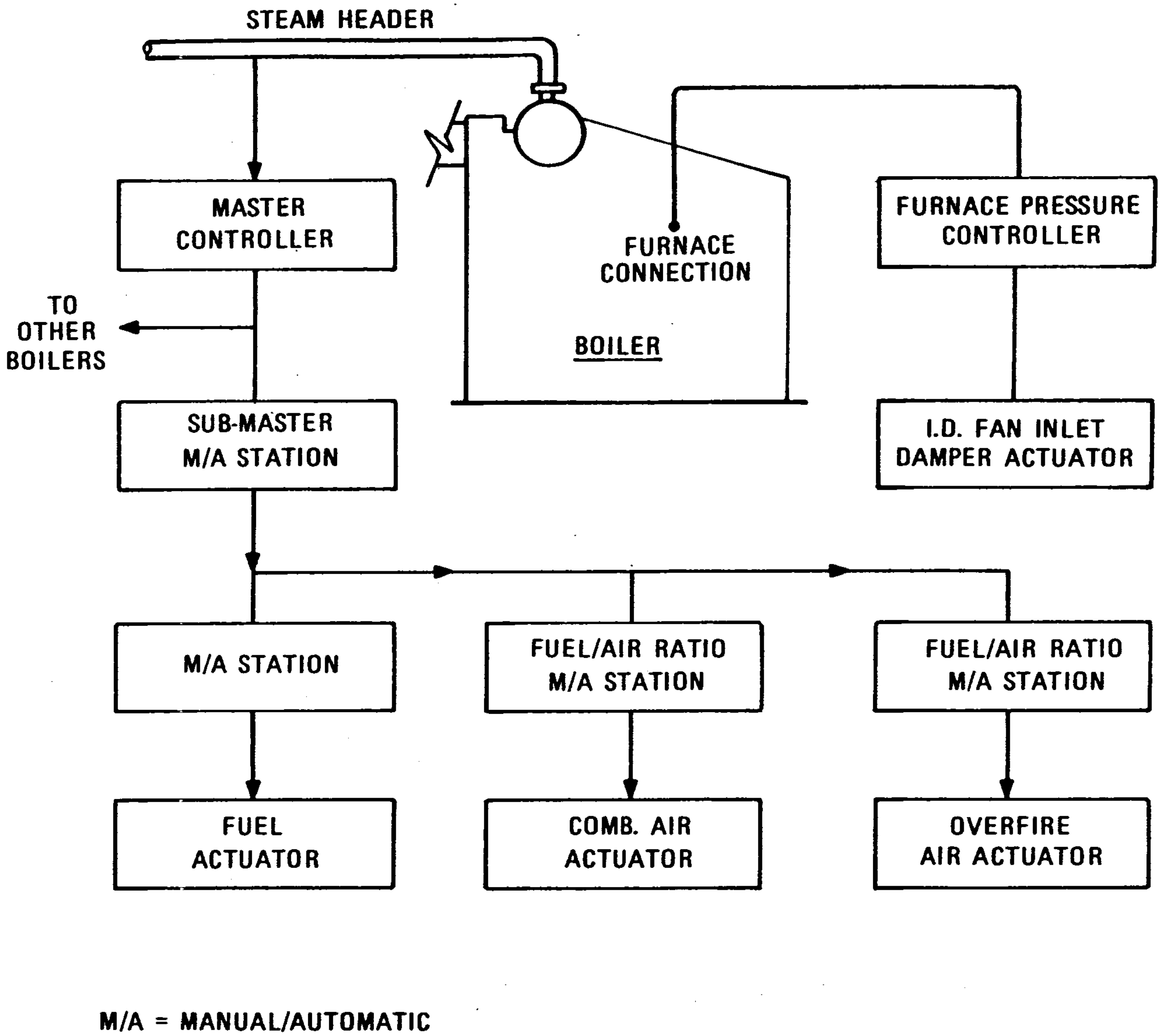


FIGURE 2-63. PARALLEL POSITIONING CONTROL SYSTEM

The master regulator is a proportional control which senses steam pressure and generates a rotary output, which moves the jackshaft. Adjustable valves are used to control and characterize the fuel oil and gas flow. These valves, together with the mechanical linkage that connects them to the FD dampers, establish the fuel/air ratio. This system is effective if fuel and air conditions remain constant and the linkage is tight and accurately adjusted. Some parallel lpositioning control systems replace the jackshaft by using a pneumatically or electronically generated fuel/air ratio and individual actuators for each fuel valve and fan damper. This approach, which is illustrated in figure 2-63, can be more accurate and more easily adjusted or trimmed. Positioning control type systems assume that the fuel and air flows always change the same amount for each change in valve or damper position. They are open-loop type control systems.

(2) **Parallel Metering Controls.** If the fuel and air flow to the burner are metered, a controller can be used which receives feedback from the metering device and further adjusts the fuel or air actuator. This ensures that when a specific fuel or air flow is demanded, it is actually delivered to the fire. This becomes a closed-loop control system and is known as parallel metering control. A parallel metering system is illustrated in figure 2-66. TM 5-810-2, High Temperature Water Heating System, requires metering controls for hot water boilers with capacities greater than 20 million Btu per hour. This type of system is also commonly used on larger sizes of steam boilers.

(3) **Oxygen Trim Control.** On most modern oil- and gas-fired boilers, as well as many coal-fired units, oxygen analyzers are used as combustion guides for the operators. Oxygen content in the flue gas verifies proper fuel/air ratio. Control systms have been developed to allow automatic adjustment of the fuel/air ratio, based upon the reading of the oxygen analyzer. These systems are called oxygen trim control systems. Figure 2-67 illustrates a typical loxygen trim control, although many other arrangements are also available. These controls are not applicable to all systems because trim adjustments are small. If the accuracy of an actuator is plus or milnus 5% and the trim required is 2%, oxygen trim will not be effective. The following conditions must exist before oxygen trim can be effectively added to a boiler.

(a) Air infiltration into the boiler must be minimal, since the trim controller cannot distinguish between air which entered through the burner and infiltration air. The flame could be starved for air at the burner and producing smoke, while still registering excess air at the analyzer. Trim control can also become unstable if the leakage rate changes.

(b) The combustion equipment must be capable of operation at the new fuel/air ratio. This can be tested manually. A burner cannot be expected to operate automatically at a low oxygen level if it cannot do so manually.

(c) The existing combustion control components must be able to operate accurately. Ocygen trim can be expected to compound any deficiency in an existing system.

2-27. BOILER SAFETY CONTROL.

Boilers are equipped with safety devices to minimize the risk of low water- and explosion-related damage. Figures 2-48 through 2-50 illustrate typical safety systems. A typical oil- or gas-fired boiler safety control system includes the following components:

— Low water-fuel cutoff switch.
— High steam pressure or high watetr temperature switch.
— Flame scanner(s).
— Gas supply high-pressure switch.
— Gas supply low-kpressure switch.
— Combustion air flow switch.
— Purge air flow switches.
— Fuel safety shutoff valves with closed-position switches.
— Fuel control valves with low-fire position switch.
— Manual valves, cocks, strainers, and traps.
— Atomizing steam or air switch(es).
— Atomizing steam or air shutoff and control valves.
— Low oil pressure switch.
High furnace pressure switch (for boilers with induce draft fans).
— Fan motor switch(es).
— Control logic.

National Fire Protection Association Standards 85A (for single burner systems),85B (for multiple burner gas-fired systems), and 85D (for multiple burner oil-fired systems) establish rules for operation of the equipment listed above. Notes on some of the more important items are given below.

a. Control Logic. Control logic provides for the following actions:

— Pre-purging the boiler below lightoff.
— Proper operation of limits and interlocks.
— Low-fire start and release to modulation sequence.
— Trial for igniter flame sequence. The igniter is shut off at the end of the trial for main flame.
— Trial for main flame ignition sequence.
— Main flame or normal operation
— Safe shutdown of the system.
— Boiler post-purge.

Electronic controls are available which receive the flame scanner signals and provide the control sequences listed above when connected to the proper switches, valves, and motor starters. The electronic controls are equipped with self-checking circuits which prove the controls to be operational. Figure 2-68 shows an electronic programming ontr incorporated into a simple control cabinet typical of a fire tube boiler application. Note that motor starters, draft

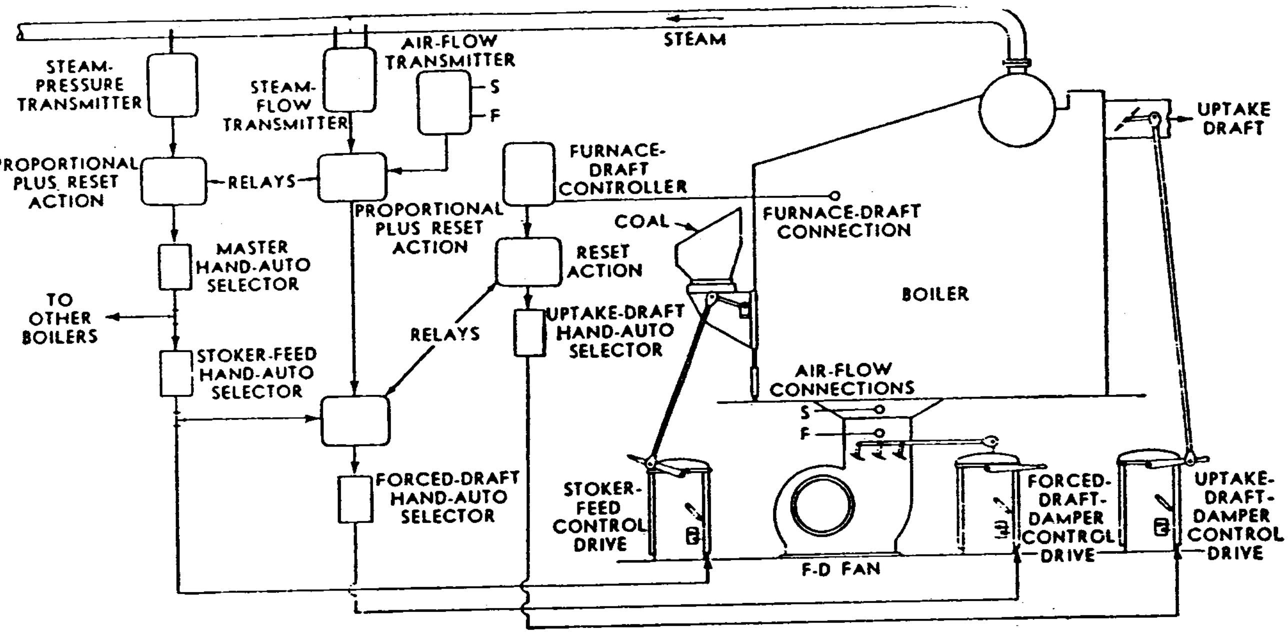


FIGURE 2-64. SERIES/PARALLEL CONTROL

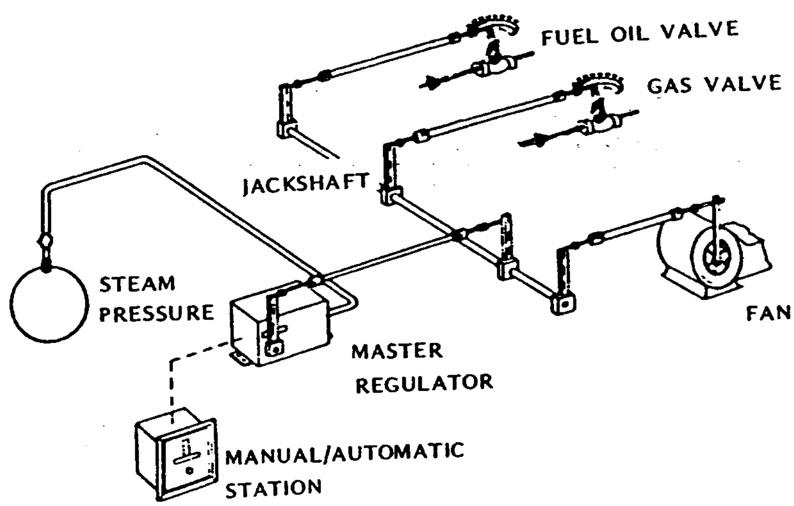
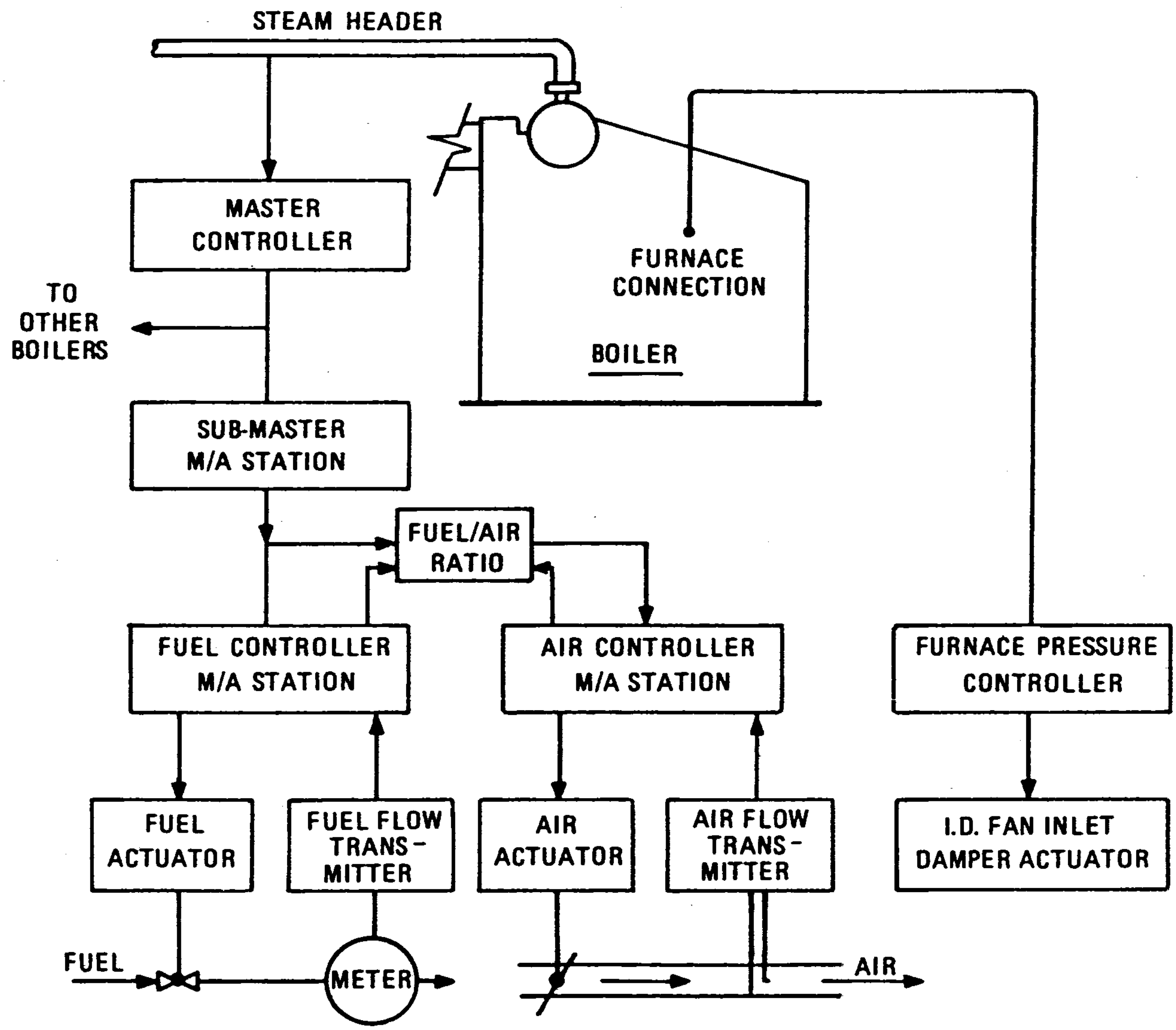


FIGURE 2-65. JACKSHAFT CONTROL SYSTEM



M/A = MANUAL/AUTOMATIC

FIGURE 2-66. PARALLEL METERING SYSTEM

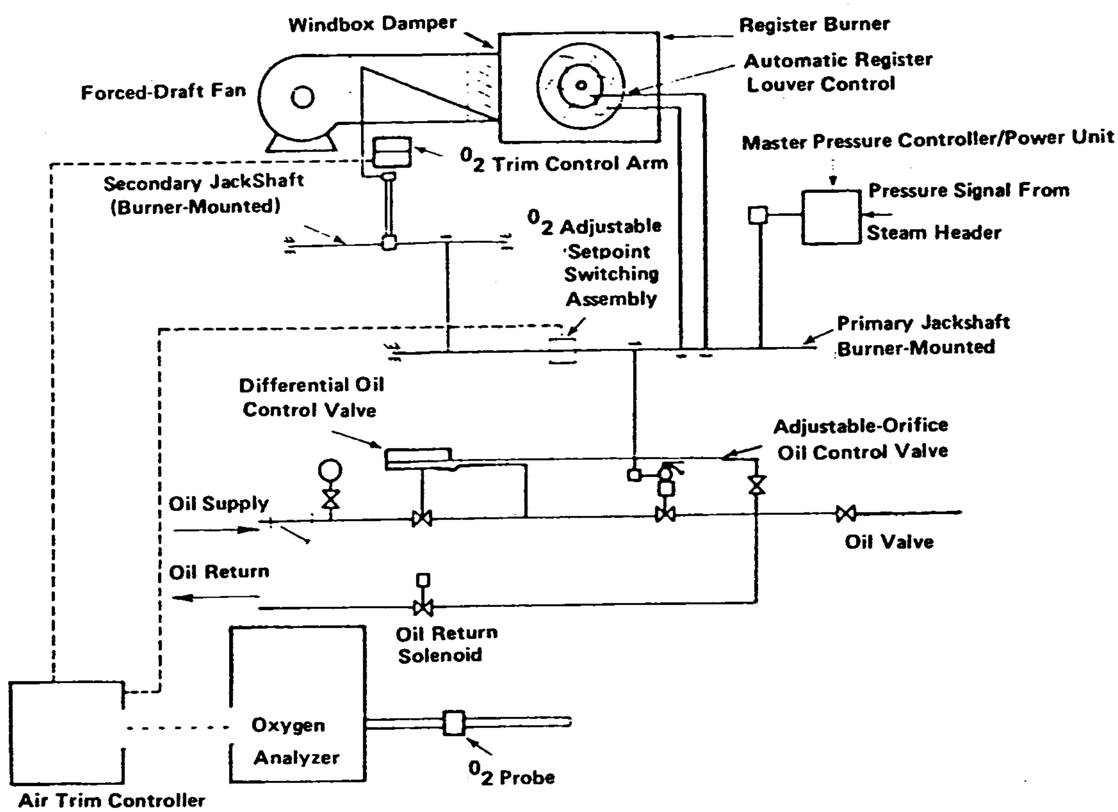


FIGURE 2-67. OXYGEN TRIM CONTROL SYSTEM

control, and a draft indicator are included. Relay logic has been commonly used in the past on multiple burner applications, but it is likely that in the near future, many new systems will be operated and monitored by programmable controllers.

b. Low-Water Fuel Cutoff. FLoat/magnet type and electrode-type low-water fuel cutoff devices are commonly used. Reference figures 2-69 and 2-70. Their purpose is to eliminate the major cause of boiler failure, firing a boiler with a low water level. If such a condition exists, the limit circuit is opened and fuel to the boiler is shut off. Because of its importance, the low-water fuel cutoff is a device that requires manual reset. The electrode type low-water fuel cutoff uses probes or electrodes to sense the water level. When the water level is above the low- water electrode, electricity is conducted to ground and a sensing relay coil is energized. Another relay is used to provide the manual reset feature required. Momentary electric circuitry can be provided to bypass the low-water fuel cutoffs to allow blowdown of the equipment without disrupting normal operation.

c. Pressure and Temperature Switches. A variety of different types of pressure switches are required to measure the wide range of pressures present in a boiler. Pressurs range from a few inches of water in the furnace to hundreds of pounds per square inch in the steam drum. Figure 2-71 illustrates a Bourdon-tube type pressure element with mercury-filled switch typicallyused for applications in the range of 5 to a few hundred psig. Diaphragm-type mechanisms with snap- action switches, as shown in figure 2-72, are used are air pressur measurements in the inches of water range. In both cases a change in system pressure causes the sensing element to deflect, activating the switch mechanism. Temperature switches can use liquid- or vapor-filled bulbs or bimetallic elements to activate similar switch mechanisms (reference figure 2-73).

d. Flame Scanners. Flame scanners which view the ultraviolet range of light are commonly called UV scanners. Lead sulfide type scanners which view the infrared and visible range of light are also common. Self-checking scanners, like the UV scanner shown in figure 2-74, are equipped with shutters thta allow the scanners electronic controls to prove that all of the scanner components are properly functioning. New types of scanners and electronics are also available which measure the frequency of the light observed and account for the fact that the base of a flame generates light at a frequency of many hundred cycles per second, while the tips generate light less than 60 cycles per second. Frequency scanners are especially effective in multiple burner applications because they can discriminate well between the flames from the various burners.

e. Annunciators. Figure 2-75 illustrates a typical annunciator system. Annunciators are frequently used in boiler plants to perform the following functions:

— Provide continuous monitoring of important operating conditions such as temperature, pressur, level, vibration, main flame, bearing cooling, and other conditions associated with the boiler safety control and plant systems.

— Alert operators to off-normal condition(s).

— Require operator acknowledgment of off-normal condition(s).

— Advise operator when the condition returns to normal.

2-28. ADDITIONAL CONTROLS AND INSTRUMENTATION.

There are many types of controls and instruments which are applied to Army Boiler Plants. Some provide only measurement functions, while others provide both measurement and control. Some of the common types of instrumentation for measurement and control are discussed below.

a. Air-Flow Steam-Flow Meter. The air-flow steam-flow meter, which is also commonly called a "boiler meter", is typically applied in series/parallel combustion control systems to provide the operator with a guide to control the relationship between the air required to efficiently burn the fuel and the air actually supplied. A typical air-flow stean flow meter is shown in figure 2-76, and its application is discussed in paragraph 2-26. Essential parts of the meter are: two air-flow bells supported from knife edges on a beam which is supported by other knife edges, and a mercury displacer assembly, also supported by a knife edge on the beam. The bottoms of the bells are sealed with oil, and spaces under the bells are connected to two points of the boiler setting. The point of higher draft is connected to the left-hand bell and point of lower draft to the right-hand bell. This arrangement is similar to that of a flow meter, because it consists of a device for measuring a pressure or draft differential. Flow of gases through the boiler setting follows the same law as steam or water flowing through an orifice: the pressure differrential, or "head," causing the flow is proportional to the square of the velocity. The flow meter is constructed so that movement of the pen on the chart is directly proportional to velocity. Therefore , if the airflow pen is to follow the movement of the steam-flow pen, the airflow mechanism must be compensated so that its movement is directly proportional to the flow of steam when the proper air-to-fuel ratio is being supplied. This compensation is accomplished by the airflow displacer, which is a parabolic float. l Enough weight is placed on the system to cause the displacer to be submerged in mercury when there is no pressure differential on the bells. As the gas flow through the boiler increases, the right end of the beam moves up and the effective weight of the displacer increases. This reduces the amount of beam movement and, in turn,

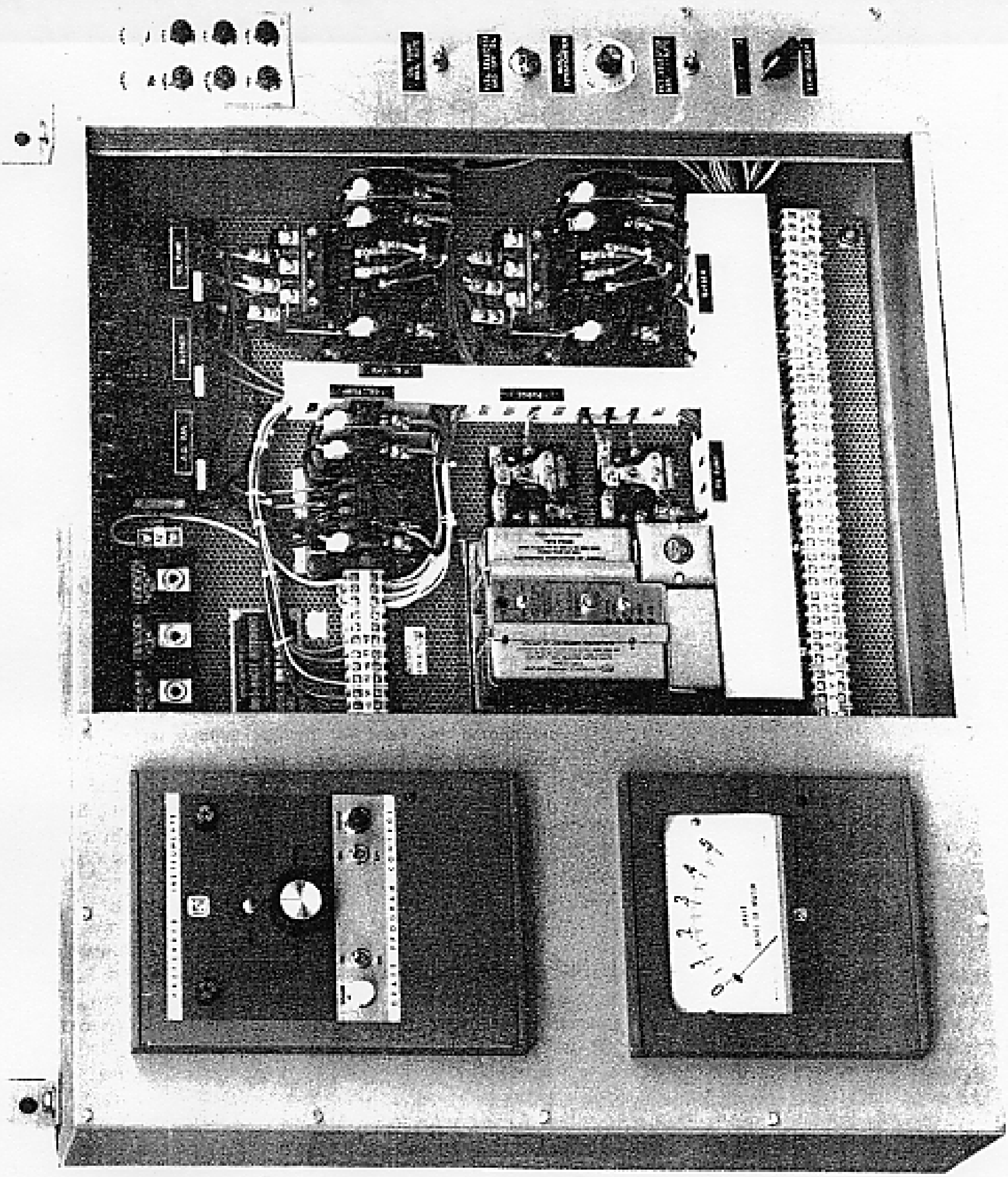
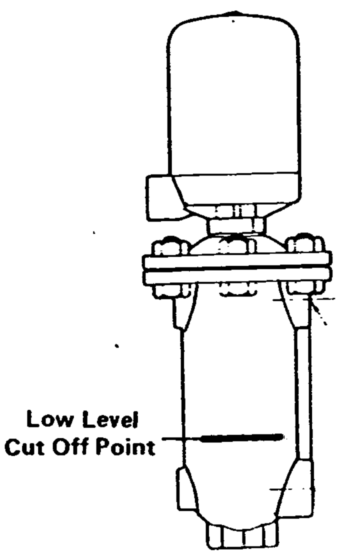
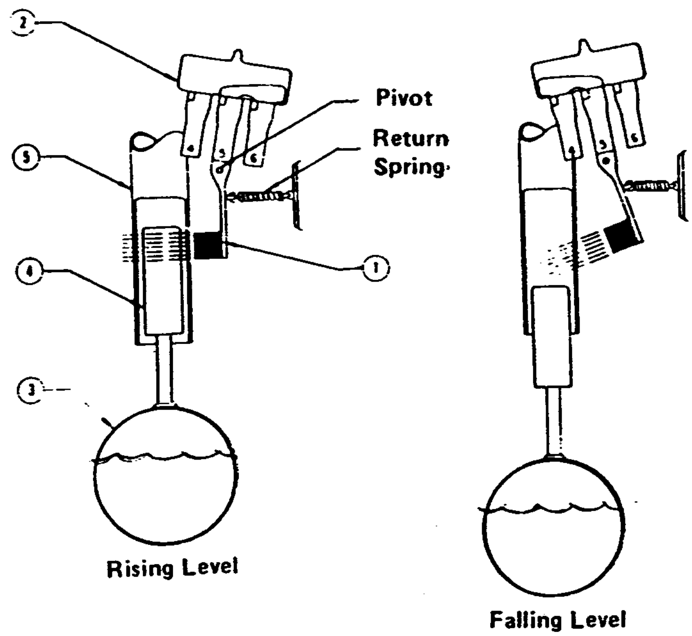


FIGURE 2-68. ELECTRONIC PROGRAMMING CONTROL IN A BOILER PANEL





OPERATING PRINCIPLE

A permanent magnet 1 is attached to a pivoted mercury switch 2. As the float 3 rises with the water level, it raises the magnet attractor 4 into the field of the magnet. The magnet snaps against the non-magnetic barrier tube 5, tilting the mercury switch. The barrier tube provides a static seal between the switch mechanism and the float, eliminating the need for flexible bellows seals, packing glands or other failure prone sealing elements. When the water level falls, such as with a low water condition, the float draws the magnet attractor below the magnetic field. The magnet swings out and tilts the mercury switch to the reverse position, actuating the low water alarm and operating the burner cutoff circuit.

FIGURE 2-69. FLOAT/MAGNET LOW-WATER FUEL CUTOFF

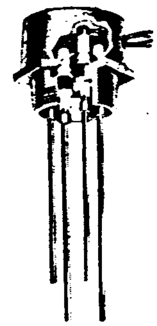


FIGURE 2-70. ELECTRODE TYPE LOW-WATER FUEL CUTOFF

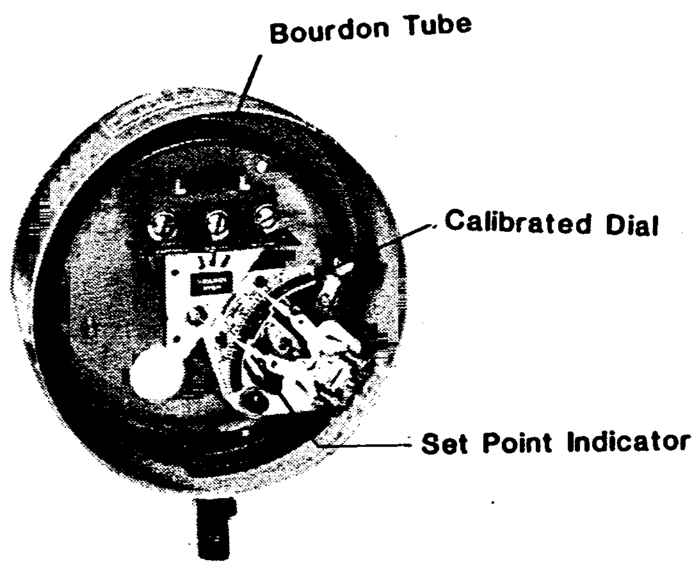


FIGURE 2-71. BOURDON-TUBE PRESSURE SWITCH

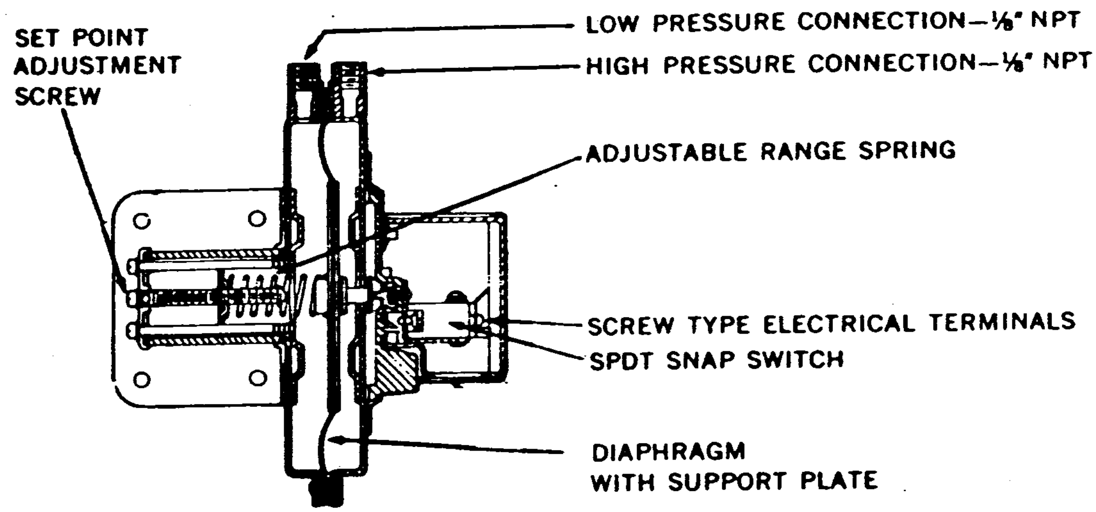


FIGURE 2-72. DIAPHRAGM PRESSURE SWITCH

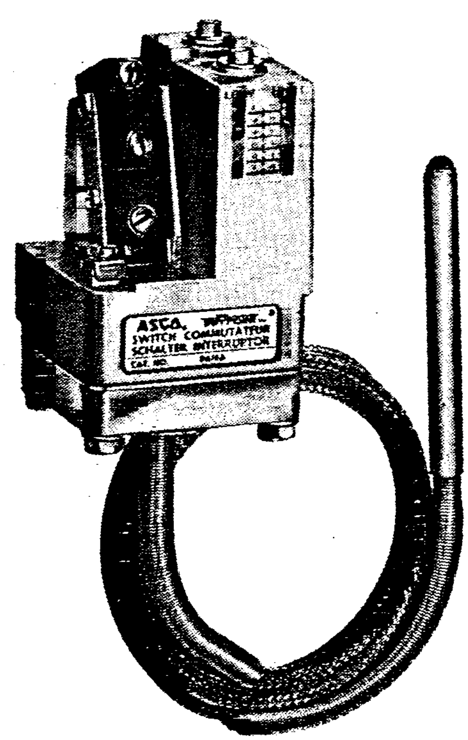


FIGURE 2-73. TEMPERATURE SWITCH

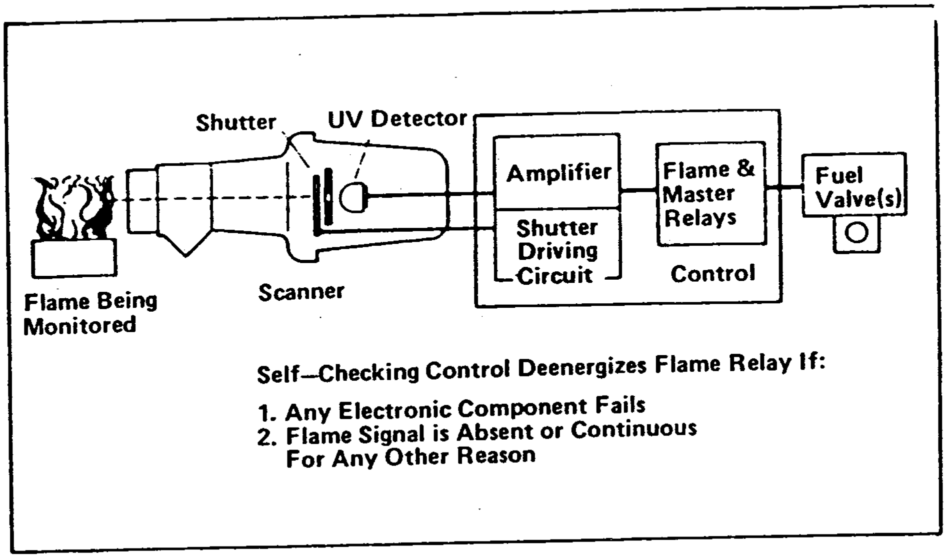


FIGURE 2-74. U-V FLAME SCANNER

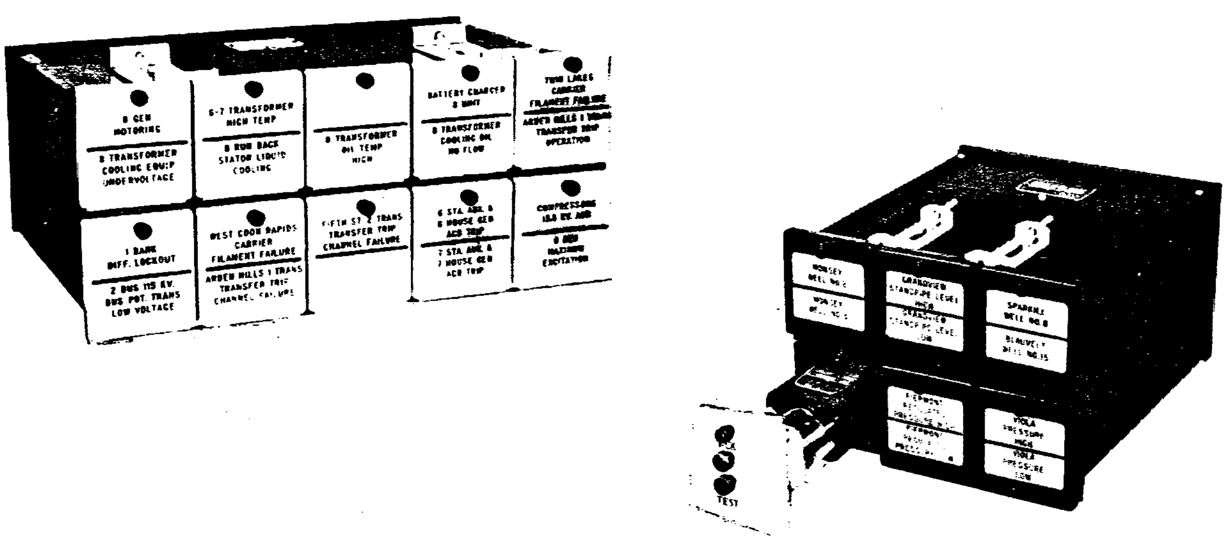


FIGURE 2-75. ANNUNCIATOR

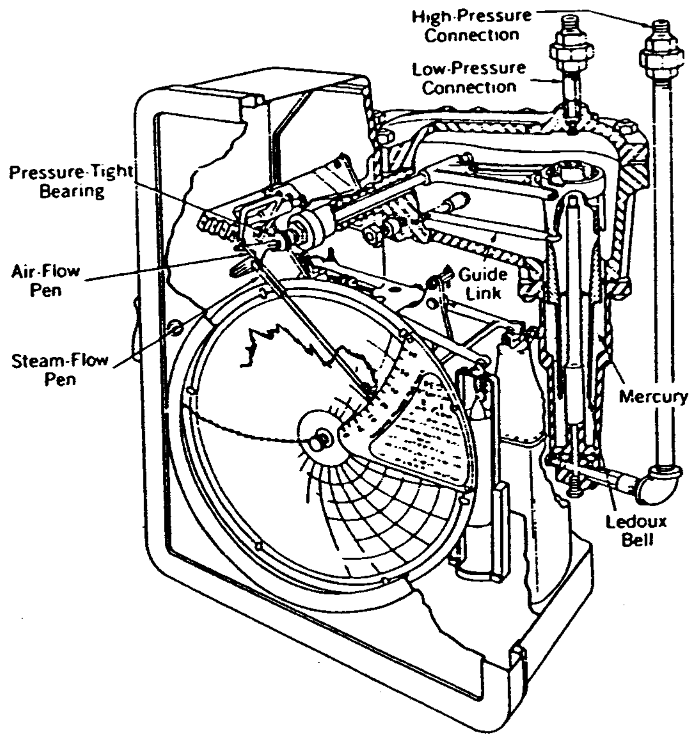


FIGURE 2-76. AIR-FLOW STEAM-FLOW METER

the amount of pen-arm movement. During initial startup, this mechanism is adjusted so that steam-flow and airflow pen recordings are together when the correct air-to-fuel ratio is being maintained. If, during operation, the airflow pen records higher on the chart than the steam-flow pen, the operator has an indication that too much air is being supplied, and vice versa.

b. Temperature Controls. Direct-acting, pilot-operated, and pneumatic or electronic temperatue controls are available. Direct-acting temperature control regulators, ashown in figure 2-77, consist of a bellows-operated valve directly connected by capillary tubing to a temperature bulb. The bellows, capillary, and bulb systems are filled with a liquid, gas, or liquid-vapor combination. The bulb is inserted wherever temperature is to be controlled, as in a feedwater heater or hot- water heater, and the valve is mounted in the steam or hot-water line supplying the heat. Temperature changes at the bulb produce an expansion or contraction of the bellows and subsequent movement of the valve stem. An adjustable compression spring opposes expansion of the bellows and provides a means to adjust the controlled temperature. Dirrct-acting regulators, while simple, reliable, and inexpensive, are of limited capacity, and the valve and 'ulb must be located within the practical length of the .pillary.

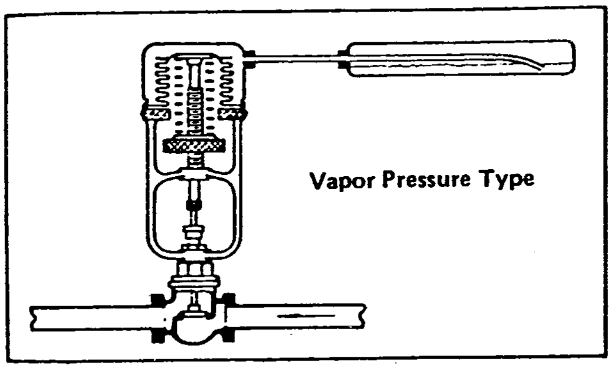
(1) **Pilot-Operated Valves.** Pilot-operated valves are available for larger capacity and more flexibility of installation. Pilot-operated valves may be operated by either internal or external pilot valves. A bulb and capillary system controls the movement of a small pilot valve. The variable loading pressur produced by the pilot valve controls teh movement of the control valve. Figure 2-78 shows a pilot-operated temperature control valve. Both direct-acting and pilot-operated temperature regulators are proportional devices.

(2) **Pneumatic and Electronic Temperature Controllers.** For improved control accuracy, two-mode (proportional plus integral) temperature controllers are available using either pneumatic or electronic components. Filled bulbs, bi-metal elements, thermocouples, and resistance temperature devices (RTD's) are used as sensing elements. The pneumatic or electronic controllers compare the sensed temperature with a setpoint and generate an output to control an actuator/valve. The actuator may be either pneumatic or electric.

c. Pressure Controls. Pressure controllers may be divided into two general types. One type maintains a set pressure in one part of the system while the pressure in the other part fluctuates or changes within certain limits. An example of this type of control is a pressure-reducing valve, which maintains a set pressure on the discharge side by controlling the flow of steam, air, or gas. The second type of control maintains a constant pressure differential between two points and also controls the flow. This type of control is often applied to a boiler feed water system to maintain a fixed differential between the prssure of water supplied at the feed valve and the pressure in the steam drum. The pressure controller may consist of either a self-contained device which opeates the regulating valve dirctrly, or a pressure-measuring device, such as a Bourdon tube, which operates a pneumatic controller. The controller positions the regulating valve or mechanism to maintain the desired conditions. Operation of pressure-reducing and differential-pressure valves depends upon a load applied to a diaphragm or piston, balancing the force exerted by a spring. The pressure load is applied to both sides of the diaphragm or piston in a differential-pressur valve, but to only one side in a pressure-reducing valve. A spring or weight is used to balance the valve in either case.

(1) **Pilot-Operated Pressure-Reducing Valve.** The valve shown in figure 2-79 is a self-contained prssure-reducing valve, which operates as follows: The deliver pressure acts on the bottom of the diaphragm, tending to push it up. This movement is opposed by the spring, and the diaphragm assumes a position dependent upon these two forces. The pilot valve is held against the diaphragm by a spring, so any movement of the diaphragm causes the pilot valve to move. One side of the pilot valve is connected to the supply pressure, and the other to the top of the piston which is in contact with the main valve. The spring on the bottom of the main valve holds the valve against the piston and supplies the force necewssary to move the piston up. When the valve is in equilibrium (that is, when flow through it is sufficient to maintain the discharge pressure at the desired level), any drop in pressure on the discharge side causes the spring to push the diaphragm down and open the pilot valve further. The pilot valve, in turn, transmits a pressure to the chamber above the piston and causes the piston to move downward. This opens the main valve and increases the flow, building up discharge pressure until the valve is once again in equilibrium. The reverse occurs if the discharge pressure rises. Discharge pressure setpoint is regulated by adjusting the spring.

(2) **Diaphragm Pressure-Reducing Valve.** The valve in figure 2-80 is equipped with a diaphragm actuator and is used for many purposes. It is commonly conneted to a pneumatic controller to serve as a pneumatic control valve. When used as a pressure-reducing valve, the pressure to be controlled is applied to the top chamber and a movement of teh diaphragm is transmitted directly to the control valve. An increase in pressure pushes the diaphragm out against the resistance of the spring and closes the valve until equilibrium is established. The controlled pressure can be varied by adjusting the compression in the spring. Figure 2-81 illustrates a self-contained diaphragm pressure-reducing valve. The outlet pressure balances the force of the spring within the valve body. The remote pressure-sensing capability



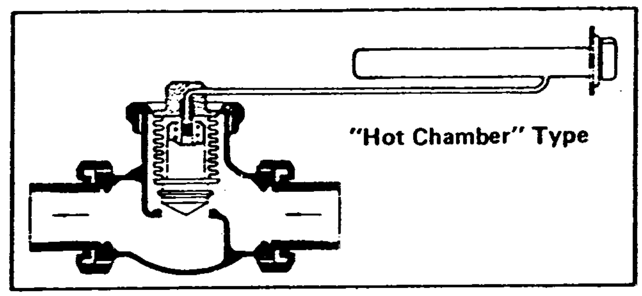


FIGURE 2-77. DIRECT-ACTING TEMPERATURE REGULATOR

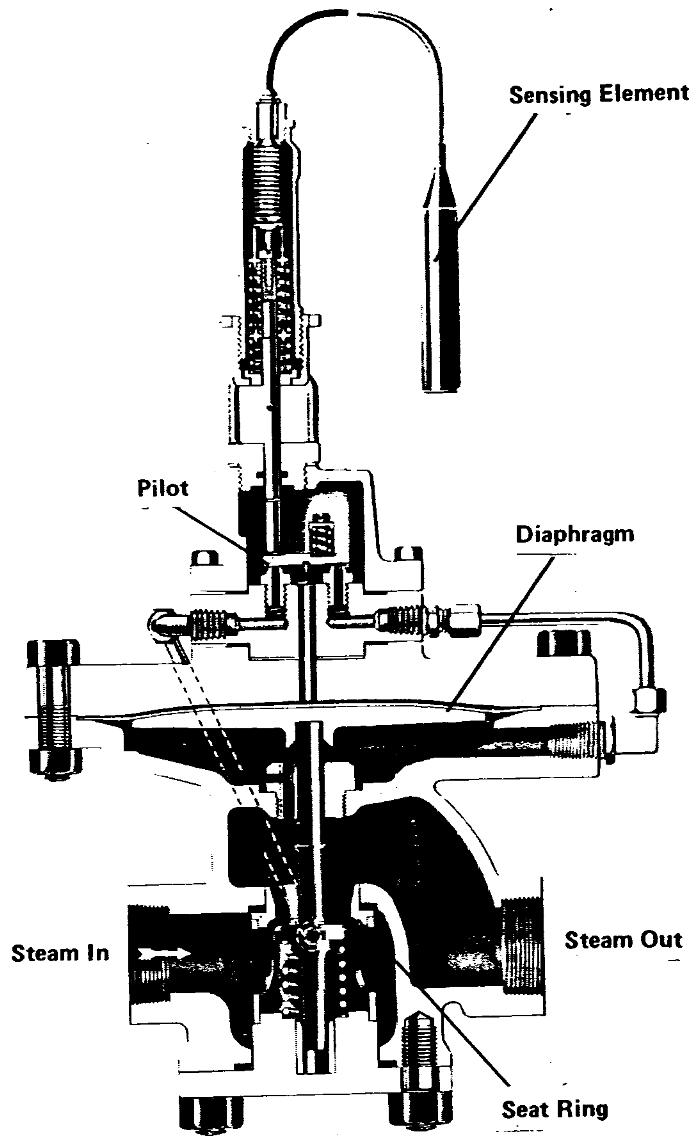


FIGURE 2-78. PILOT-OPERATED TEMPERATURE CONTROL VALVE

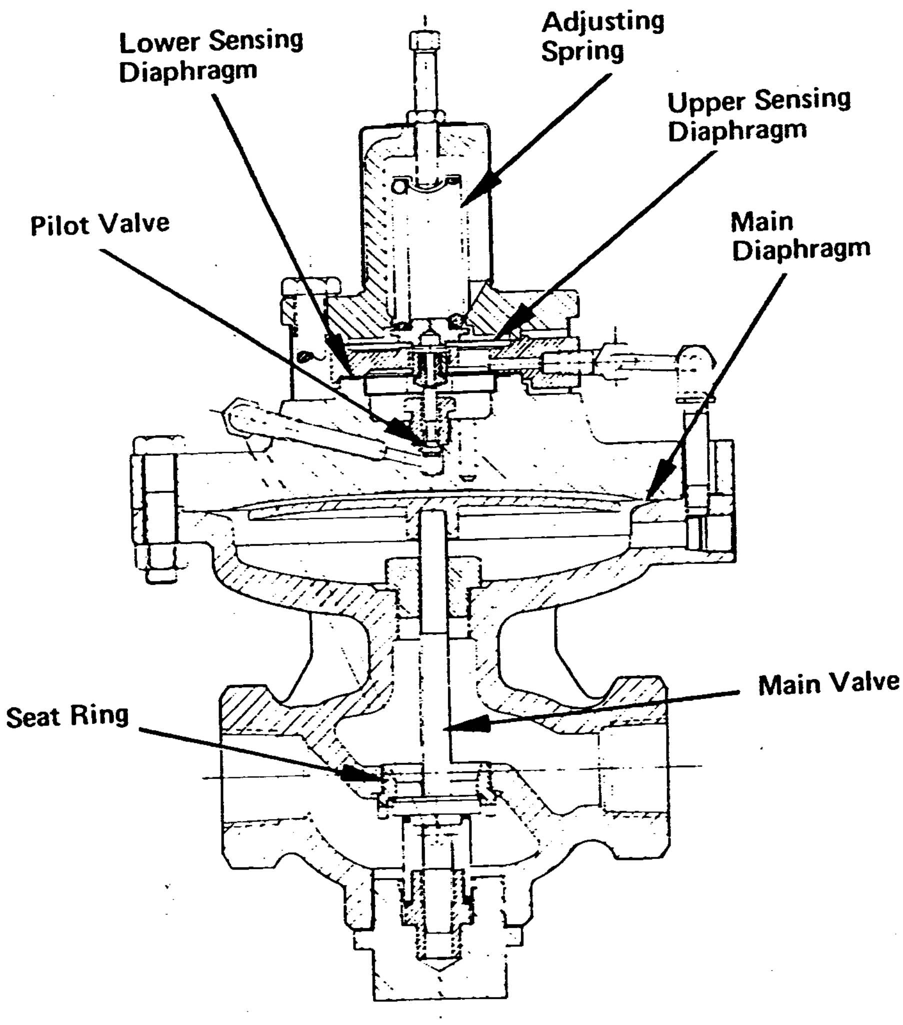


FIGURE 2-79. PILOT-OPERATED PRESSURE-REDUCING VALVE

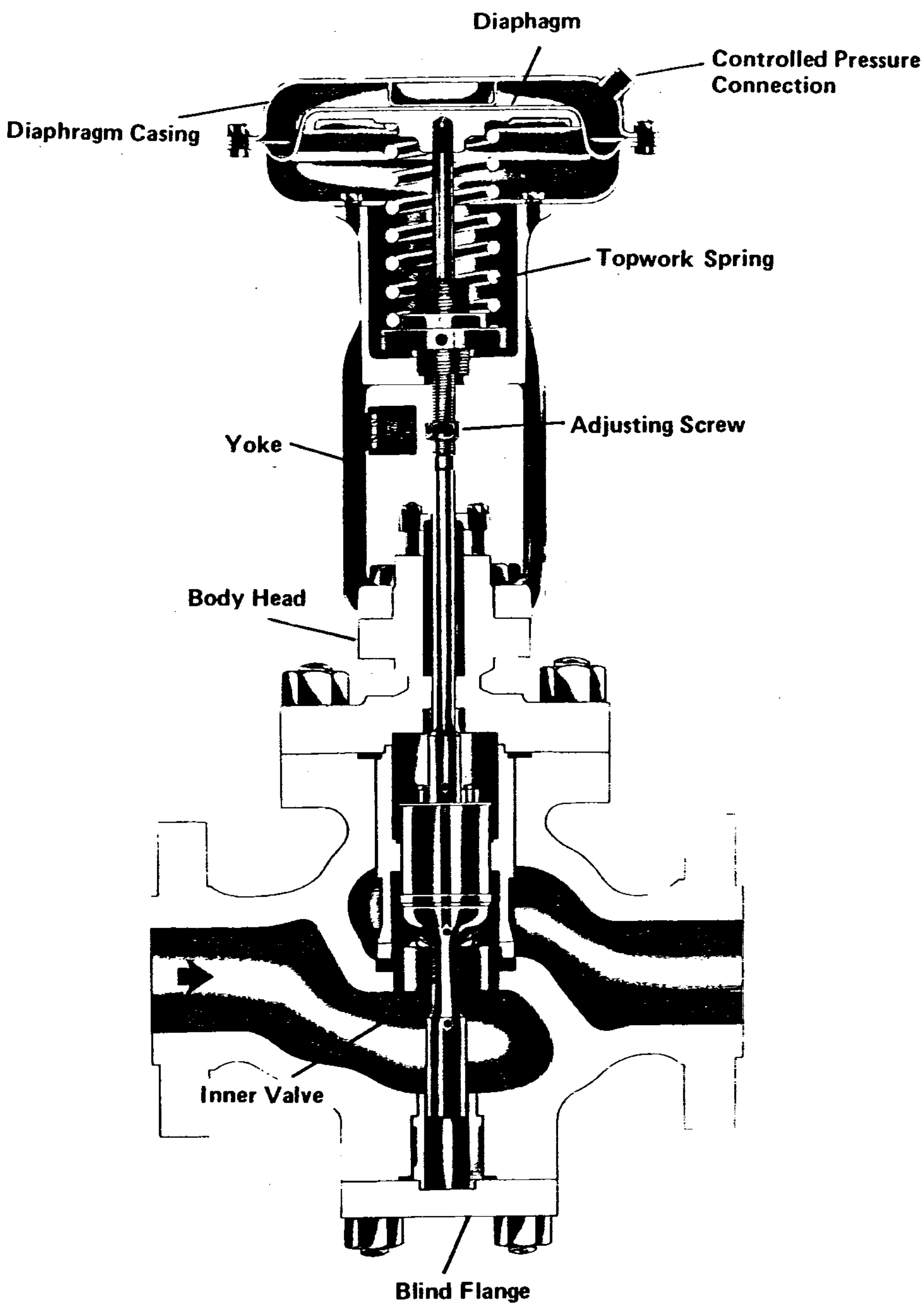


FIGURE 2-80. DIAPHRAGM ACTUATOR PRESSURE-REDUCING VALVE

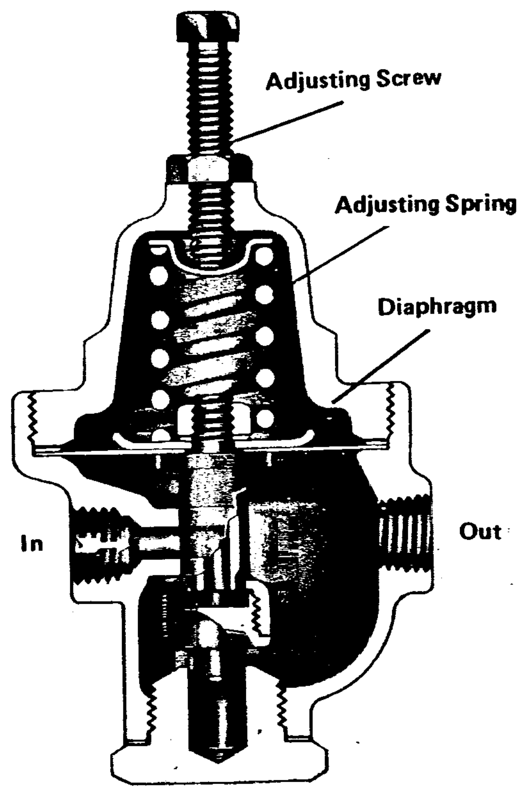


FIGURE 2-81. SELF-CONTAINED DIAPHRAGM PRESSURE-REDUCING VALVE

of the previous valve is eliminated by the simplicity of this valve.

(3) **Differential Pressure-Reducing Valve.** In the valve shown in figure 2-82, a pressure-tight chamber is provided on each side of the diaphragm, and a spring is used to control the differential between the two pressures. The top and bottom chambers are connected to the two pressures to be conrolled. When the force on the top chamber of the diaphragm is equal to the force on the bottom plus the spring force, the valve is said to be in equilibrium. If the bottom chamber pressure changes, the spring acts on the diaphragm to cause the pressures to vary simulateously, maintaining a constant differential.

(4) **Steam Differential Pressure-Reducing Valves.** Figure 2-83 illustrates a differential pressure-reducing valve typically used to control atomizing steam to oil burners. An oil sensing line is connected to the top chamber of the valve. The pressure of the oil and spring are added together to balance the pressure of the steam and to adjust the valve position. The force applied by the spring establishes the differential pressure between the oil and steam.

d. Flow Meters. Five types of flow-measuring elements are typically found in central heating plants:

— Differential pressure
— Variable area
— Volumetric/positive displacement
— Propeller and turbin
— Weirs and flumes

These measuring elements may be connected to recorders, indicators, or totalizers to provide information on plant operation.

(1) Differential Pressure Meters. Differential pressure flow meters measure the prssure loss created by fluid flow through a pipeline restriction such as an orifice, flow nozzle, or venturi (reference figure 2-84). Water, steam, or gas flowing through a restriction increases in velocity and decreases in prssure. The pressure drop increases by the square of flow or velocity. Thus, if an orifice has a pressure drop of 100 ilnches of water at 100 percent flow, the pressure drop is only 1 inch of water at 10% flow. This explains why it is difficult for differential flow meters to provide accurate information at low flow rates. Figure 2-85 illustrates a steam sflow recorder equipped with a Ledoux bell. The Ledoux bell is shaped to take the square root of a signal from the line restriction. The movement of the bell is transmitted through a system of levers and links to a pen which records the flow on a chart. Pneumatic transmitters like the one shown in figure 2-86 are available to replace the function of the Ledoux bell. Very accurate electronic transmitters are also available.

(2) **Variable Area Meters.** A variable area or rotameter is shown in figure 2-87. In this type of meter, the fluid passes upward through a tapered meter tube which contains a float. The float position indicates the rate of fluid flow.

(3) **Volumetric Meters.** Volumetric or positive displacement meters are frequently used to measure gas, oil, or water and are equipped with a dial register that indicates the total volume of flow. Figure 2-88 illustrates a positive displacement-type meter for oil service. These meters can also be equipped to generate flow rate signals.

(4) **Turbine Meters.** In these turbine type meters, the rotational velocity of the propeller or turbine is proportional to the fluid velocity or flow. FLow rates are measured by electonic equipment which senses this rotational velocity and converts it to a volumetric reading. Figure 2-89 illustrates a turbine meter.

(5) **Weirs and Flumes.** Changes of liquid flow rates through the weir or flume causes a change in the upstream liquid level. Float-actuated level indicators are used to indicate flow rate.

e. Pressure Gages. A number of devices may be used to measure pressure, with the Bourdon tube being the one most commonly applied in boiler plants.

(1) **Bourdon Tube Pressure Gage.** The measuring element of the Bourdon tube gage (figure 2-90) is a tube of oval cross-section bent into an arc which is closed at one end and connected to the source of pressure at the other. This oval cross-section changes its shape with changes in pressure. When the pressure within the tube increases, the cross-section tends to become circular and causes the tube to straighten. The movement of the free end of the Bourdon tube is transmitted through a ger sector and pinion to a pointer which indicates the change in pressure. The exact shape of the tube and the material from which it is made depend upon the pressure range for which the gage is to be used. This type of gage can be used to measure pressures either above or below atmospheric. When using a gage to measure steam pressure, a siphon or water leg must be used to ensure that the hot steam does not come into direct contact with the tube.

(2) **Other Types of Pressure Gages.** Diaphragm-type gages are used for measurement of small differentials in inches of water where total pressure does not exceed about 1 psig. For high static pressures, opposed bellows gages (figure 2-91) are available to read a wide range of differential pressures. They are suitable for reading fluid pressure drops through boiler circuits and can be used to measure differentials from 2 to 1000 psi at pressures up to 6000 psig, far above the ranges used in Army Central Boiler Plants. More sophisticated devices for the measurement of pressures and differential pressures are also on the market. Generally described as transducers, they are based on a variety of principles. Some examples are transducers using a strain gage mounted on a diaphragm, or those using a crystal which undergoes a change in electrical resistance as the element is deformed. Since such elements require

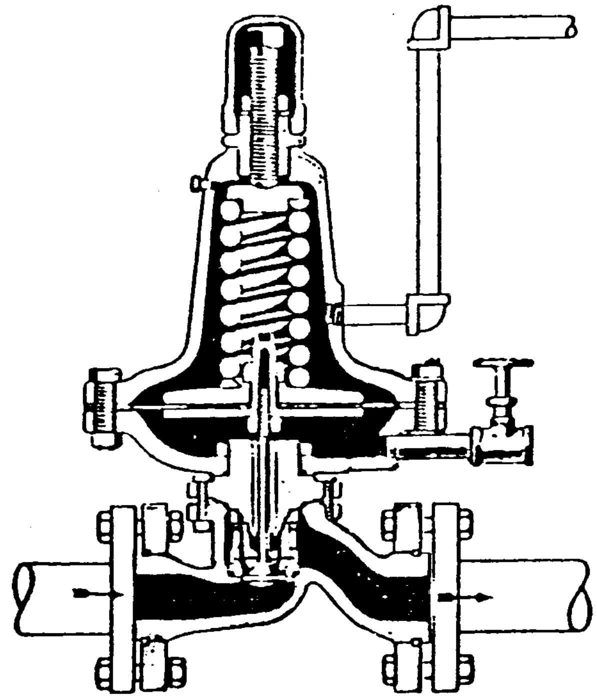


FIGURE 2-82. DIFFERENTIAL PRESSURE-REDUCING VALVE

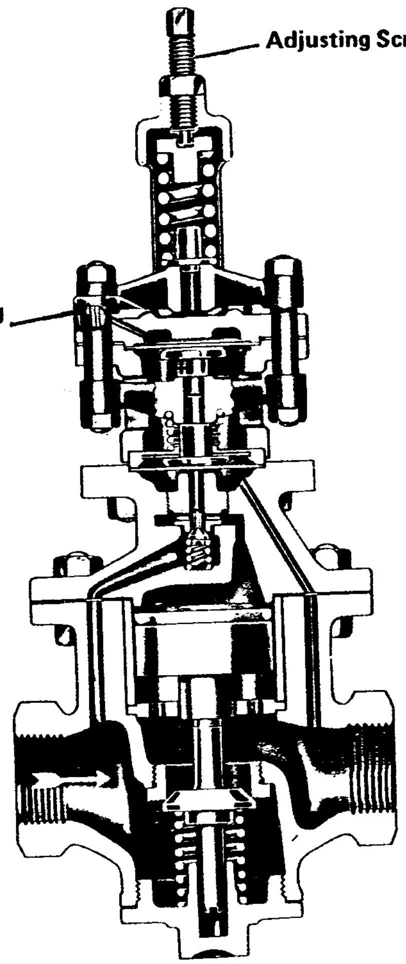


FIGURE 2-83. STEAM DIFFERENTIAL PRESSURE-REDUCING VALVE

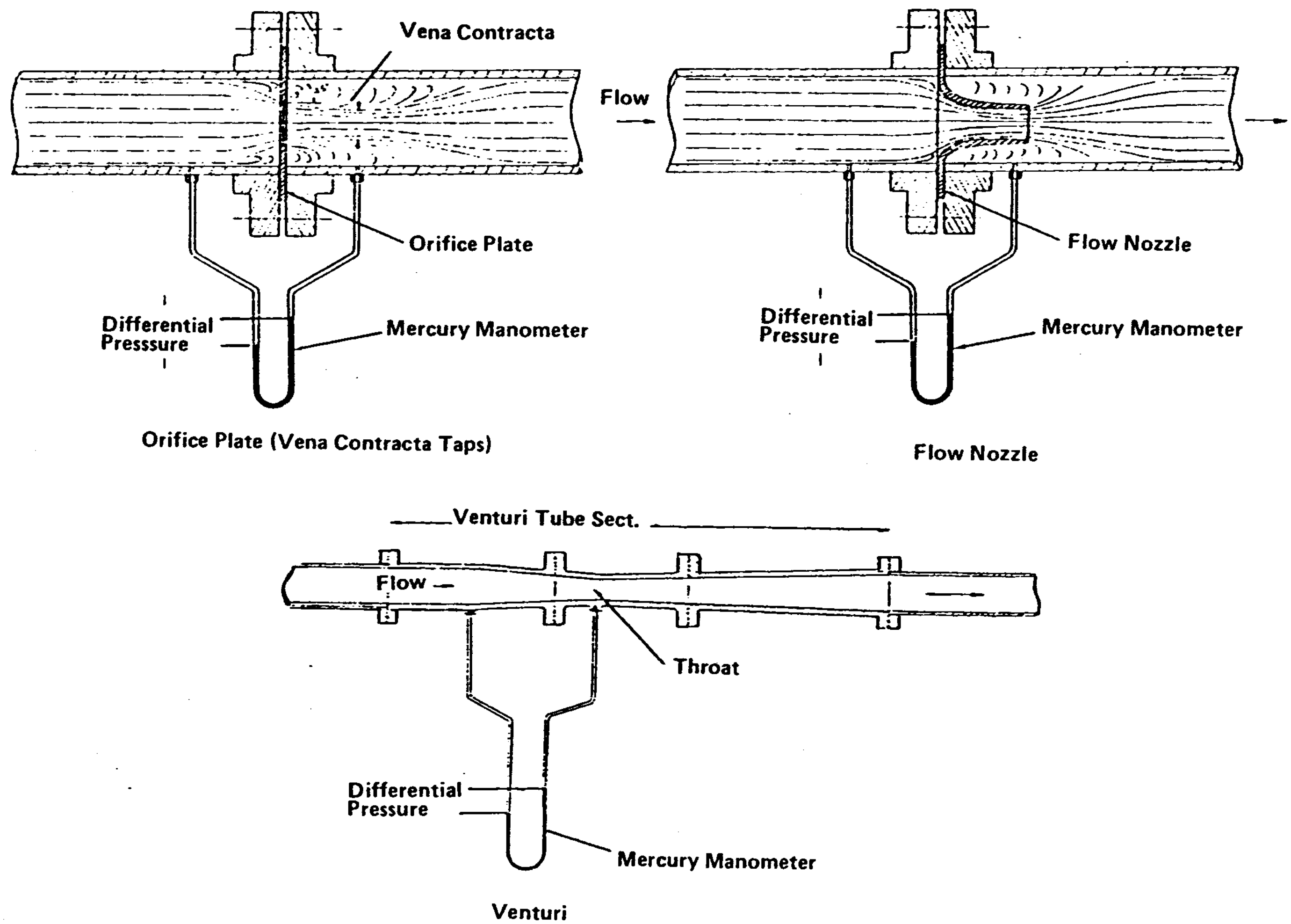


FIGURE 2-84. ORIFICE, FLOW NOZZLE, AND VENTURI

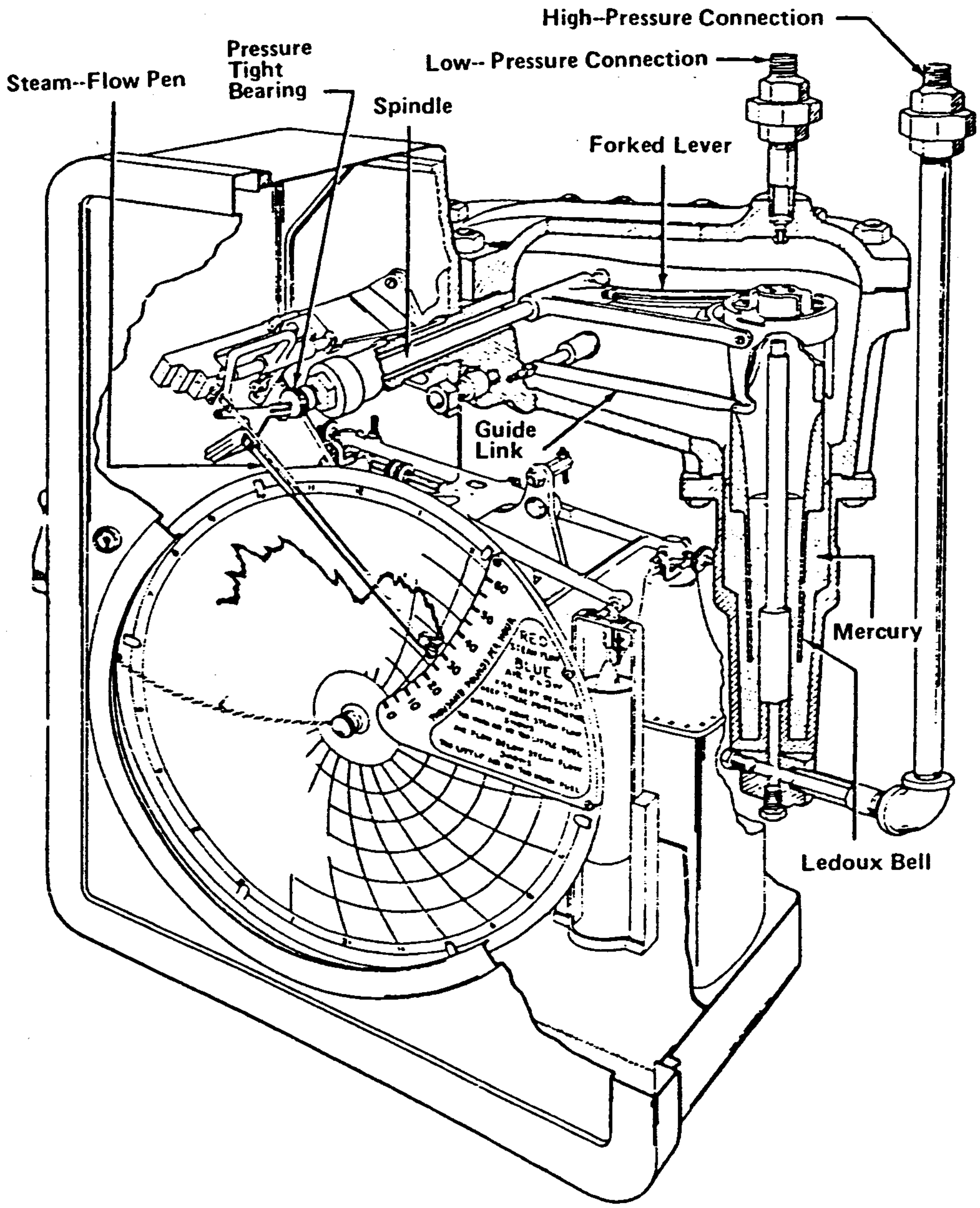
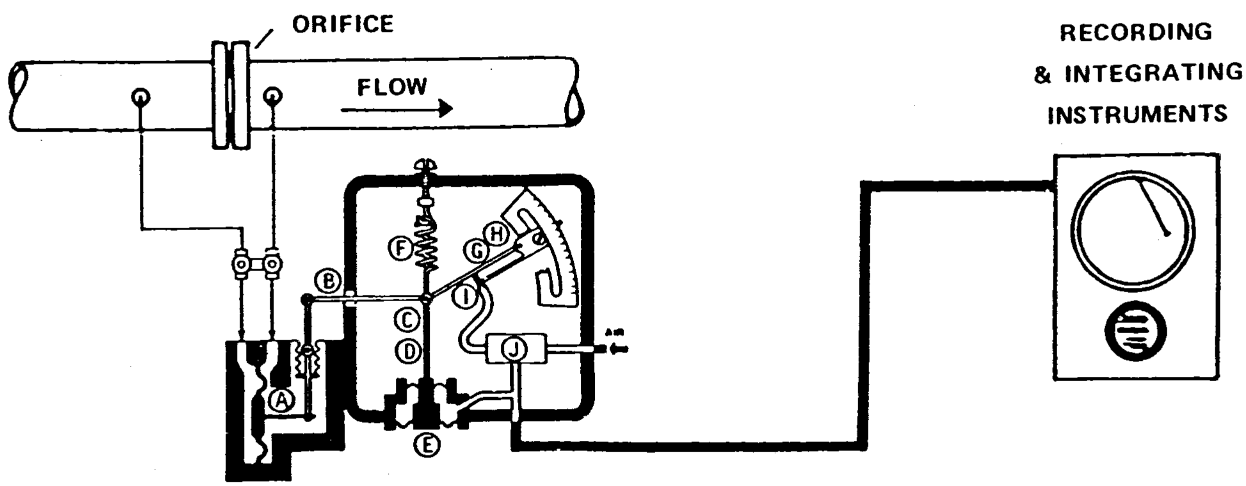


FIGURE 2--85 STEAM FLOW RECORDER



A.	DIFFERENTIAL DIAPHRAGM	F.	ZERO SPRING
B.	LINK	G.	BAFFLE
C.	FLOATING PIVOT	H.	PIVOT
D.	LINK	I.	NOZZLE
E.	FEED BACK DIAPHRAGM	J.	REVERSING RELAY

FIGURE 2-86. PNEUMATIC DIFFERENTIAL PRESSURE TRANSMITTER

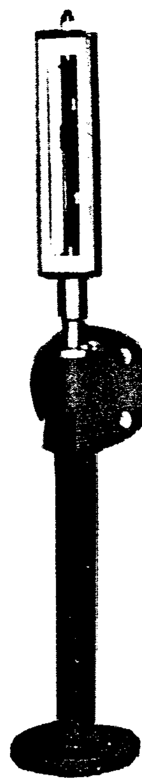


FIGURE 2-87. ROTAMETER

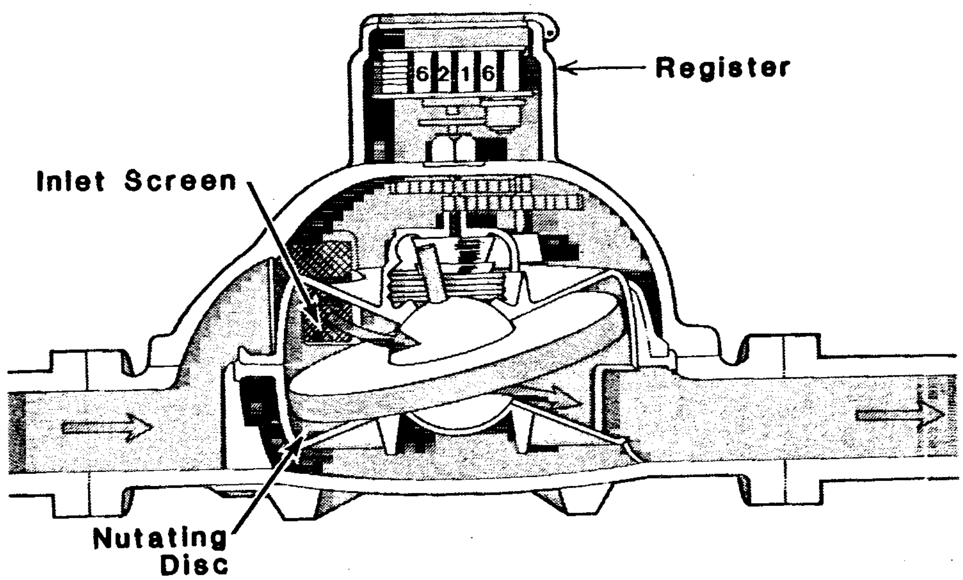


FIGURE 2-88. POSITIVE DISPLACEMENT METER

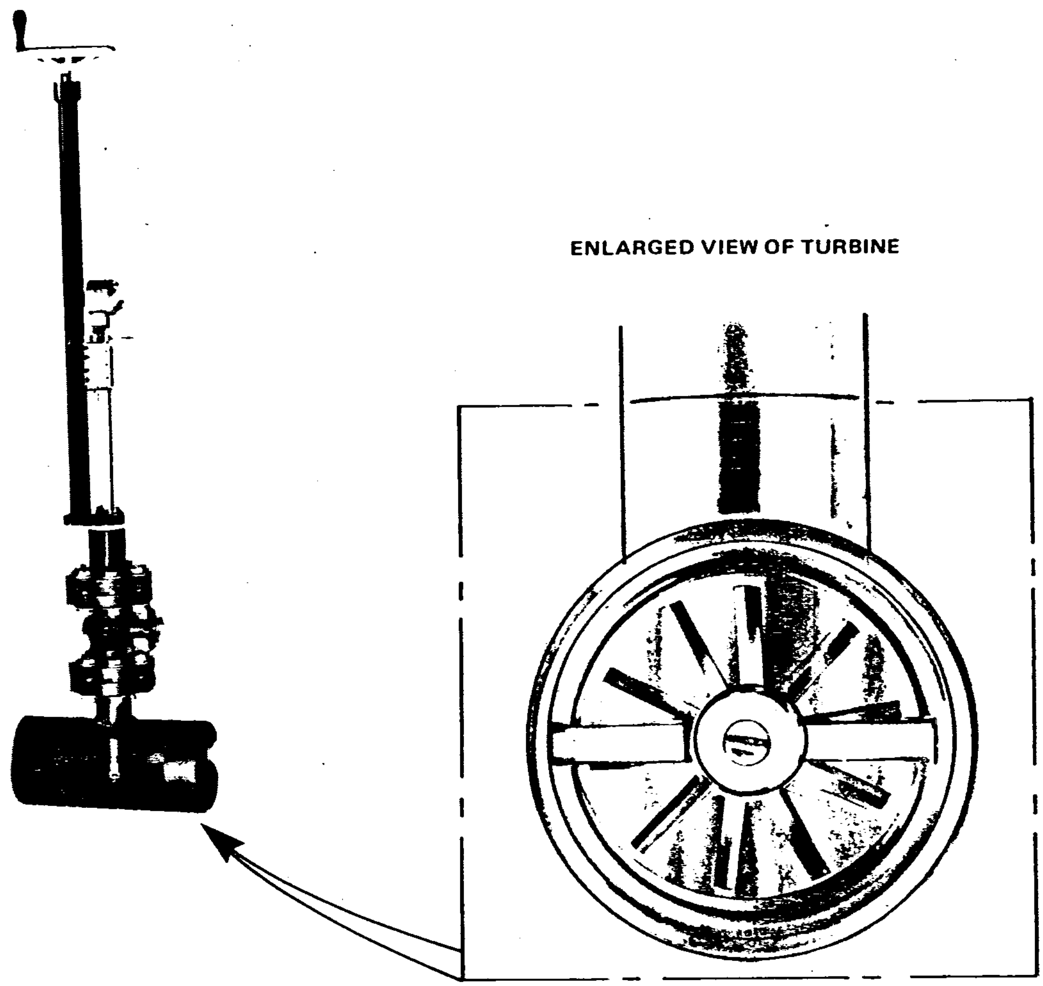


FIGURE 2-89. TURBINE METER

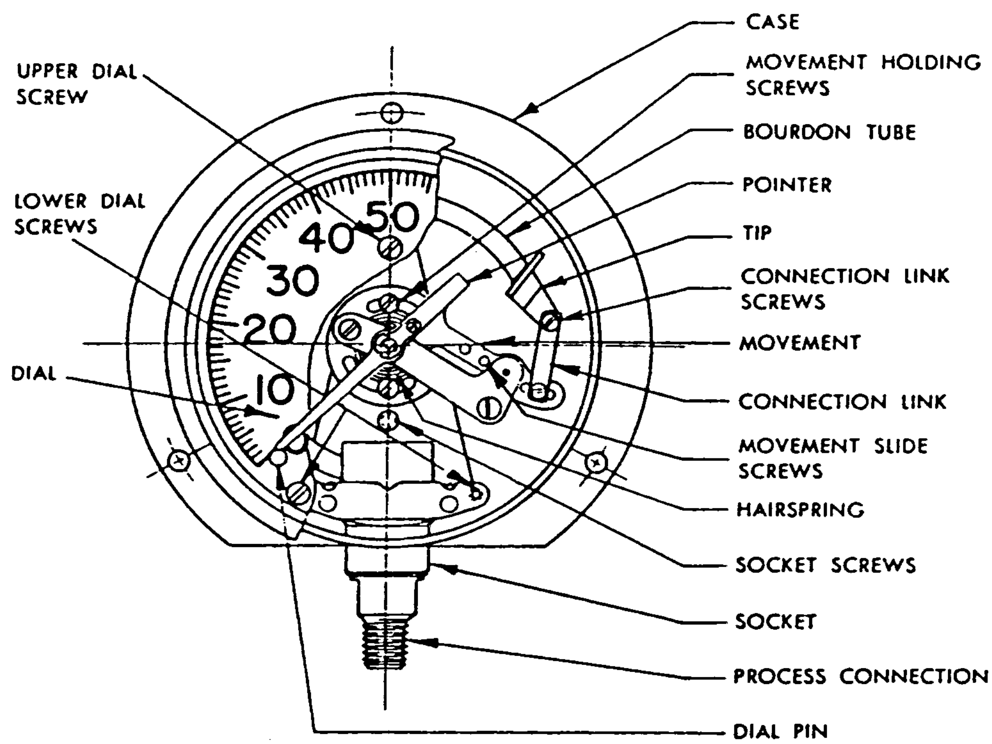


FIGURE 2-90. BOURDON TUBE PRESSURE GAGE

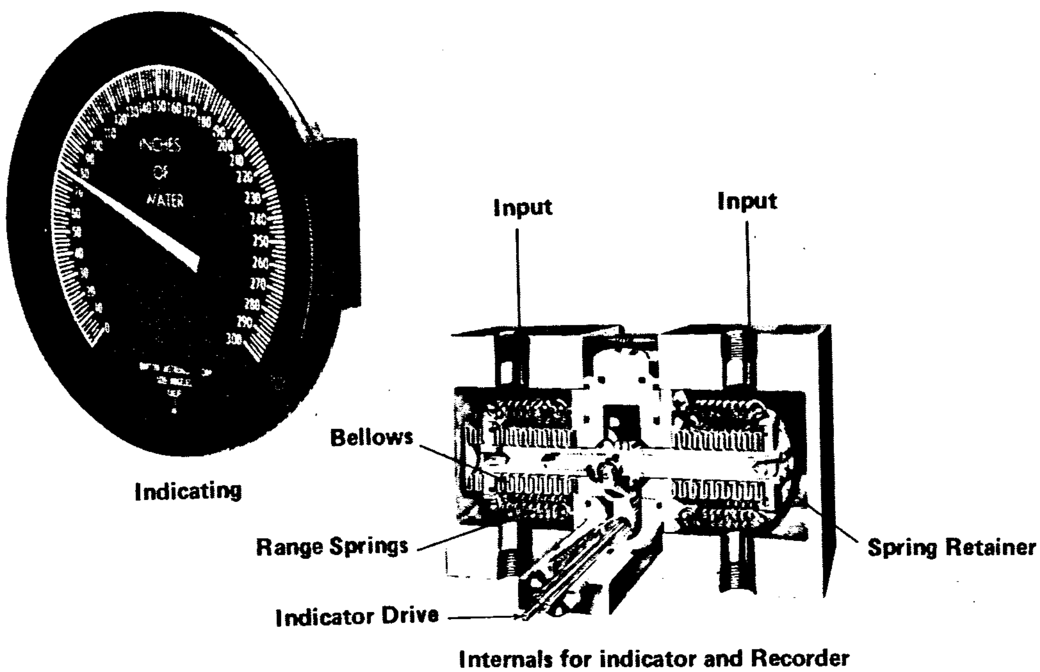


FIGURE 2-91. OPPOSED BELLOWS DIFFERENTIAL PRESSURE GAGE

elaborate and frequent calibration, they have not historically been used as basic instruments in Army Central Boiler Plants. However, with their rapidly increasing reliability and ease of application, pressure transducers are finding wider application and will become more frequently seen.

f. Draft Gages. A draft gage is a form of pressure gage which measures pressures in the range of inches of water column. Draft gages typically are used to measure air pressures at the furnace, windbox, and boiler outlet. Inclined and U-tube manometers and diaphragm-type draft gages are common.

(1) **Manometers.** Figure 2-92 shows an inclined and U-tube manometer. The inclined manometer consists of an inclined leg and a reservoir filled with gage oil. In a typical inclined manometer the length of the scales is 12 inches for each 1 inch of water draft measured. It is important to use the gage oil for which the manometer ws designed to obtain accurate readings, since the gage reading is dependent on the density of the oil. This information is normally stamped on the manometer body.

(2) **Diaphragm Draft Gages.** The draft gage shown in figure 2-93 uses a thin metal diaphragm fastened to a flat cantilever spring. Atmospheric pressure is exerted on top of the diaphragm, and draft on the bottom. This pressure differential causes the diaphragm to move down. The downward movement is resisted by the cantilever spring. The motion of the cantilever spring is transmitted through a chain to the counterbalanced pointer and produces an indication on the scale which is directly proportional to the draft. The pointer in this gage moves in an aarc. The area of the diaphragm is large, thus greatly magnifying the force available for moving the pointer.

g. Glue Gas Analyzers. A variety of flue gas analyzers may be installed in Central Boiler Plants. Their purpose is to allow the operator to more efficiently monitor and operate the plant and to ensure compliance with environmental regulations.

(1) **Oxygen Analyzer.** The percentage of oxygen in the boiler flue gas is an effective combustion guide. Continuous monitoring of oxygen levels scan be accomplished by using a zirconium oxide oxygen analyzer shown in figure 2-94. The analyzer consists of a sampling system which pulls flue gas into the zirconium oxide cell located in an electric furnace. At approximately 1700 F, the cell responds to the percentage of oxygen in the flue gas by generating a small electric current. Analyzer electronics evaluate the electric current from the cell and produce an output signal to an indicator, recorder, or combustion trim control system.

(2) **Carbon Monoxide Analyzer.** Carbon monoxide (CO) in the flue gas indicates incomplete combustion due to either a lack of sufficient combustion air or inefficient mixing of the fuel and air. Modern boiler plants may be equipped with CO analyzers to provide the operator with an indication of how much CO exists. The CO in the flue gas is converted to an electric signal through oxidation on the surface of a catalyst-coated element and measurement of the heat produced. Analyzer electronics provide an output signal proportional to the concentration of CO in the sample stream. The output is sent to a recorder, or occasionally used as a trimming input to the combustion control system. Historically, reliability has been a problem with Co analyzers. However, as technology improves, their reliability is expected to improve, and their use in combustion control systems will become more common. Co trim is applicable only to oil- and gas-fired boilers, and its use is limited by essentially the same criteria as those noted for oxygen trim systems in 2-26d(3).

(3) **Smoke Density Indicator.** Coal- and oil-fired plantrs are often provided with smoke-density indicators and recorders where smoke is particularly objectionable. These units usually consist of a light source and photoelectric cell mounted on opposite sides of the stack, an electronic system to condition the cell signal, and an indicator or recorder mounted on the panel.

(4) **SO_2 and NO_x Analyzers.** Continuous monitoring of pollutants is sometimes required by environmenta' regulations. Sulfur dioxide (SO_2) and oxides of nitrogeı. (NOx) are the pollutants most commonly required to be monitored. Several different types of analyzers are available to monitor pollutants by extractive means: non-dispersive infrared (NDIR), ultraviolet photometric (UV), and electrochemical analyzers for both SO_2 and NOx, chemiluminescence analyzers for NOx, flame photometric and fluorescence analyzers for SO_2. Each of these types has its own advantages and disadvantages, and the technology is rapidly changing. A detailed analysis of up-to-date technology and environmental agency requirements is recommended before analyzers of this type are installed.

h. Temperature Gages. Temperature is measured by a number of devices, the most common of which is the mercury- or liquid-filled industrial thermometer. When remote indication or recording of temperature is needed, for example to monitor flue gas temperature leaving the boiler, then bulb/capillary, pneumatic, or electronic sensors and transmitters can be provided and connected to an indicator or recorder. Temperature devices can also be used to provide feed forward or feedback signals to a control system (reference paragraph 2-28b(2)). Figure 2-95 illustrates a typical recording thermometer.

i. Recorders. A variety of recorders is available to provide a permanent record of almost any variable which can be measured. Some recorders may be connected directly tc the instrumentation which provides the recorded signal, such as the air-flow steam-flow meter shown in figure 2-

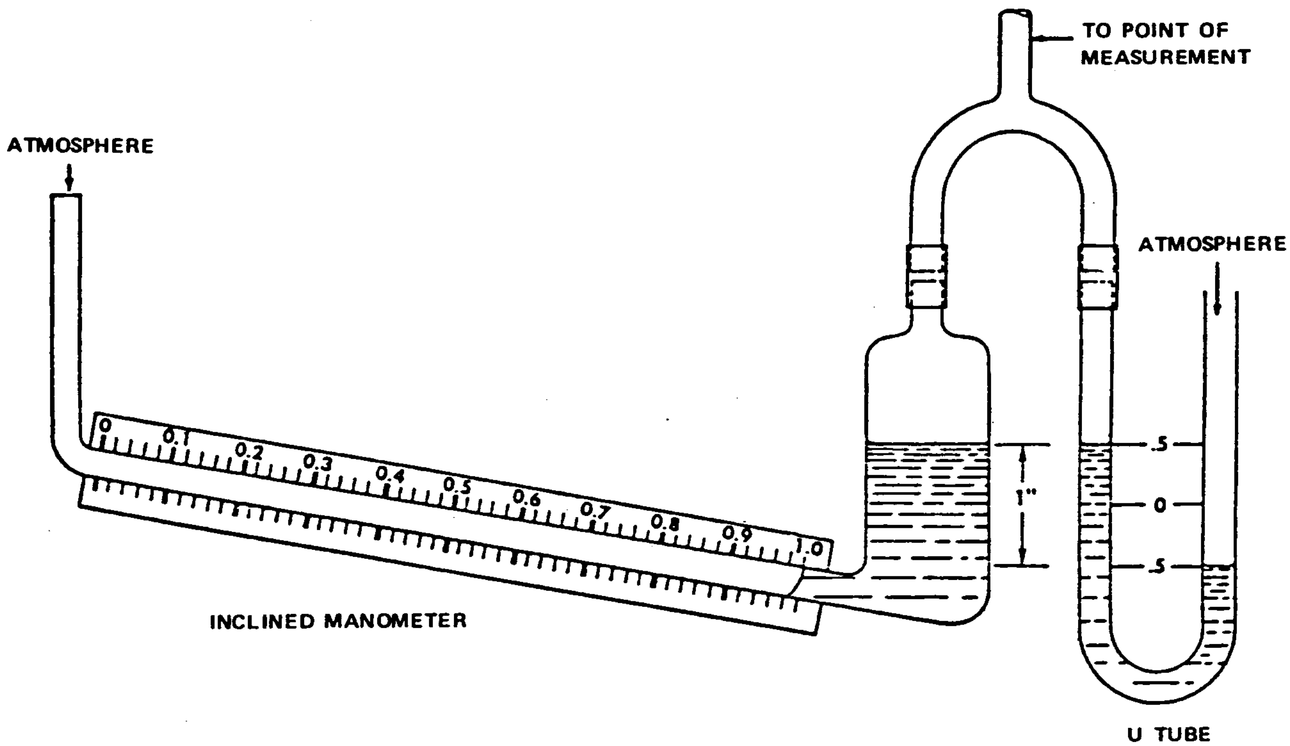


FIGURE 2-92. INCLINED/U-TUBE MANOMETER

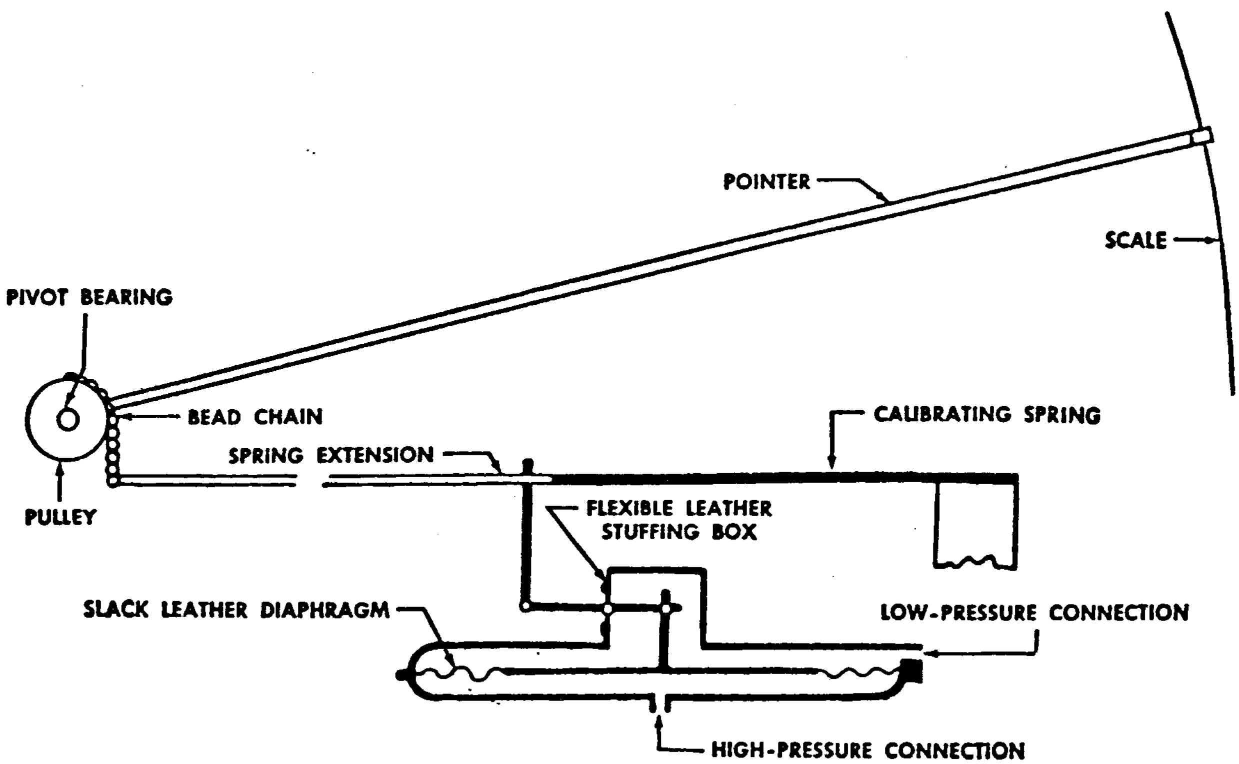
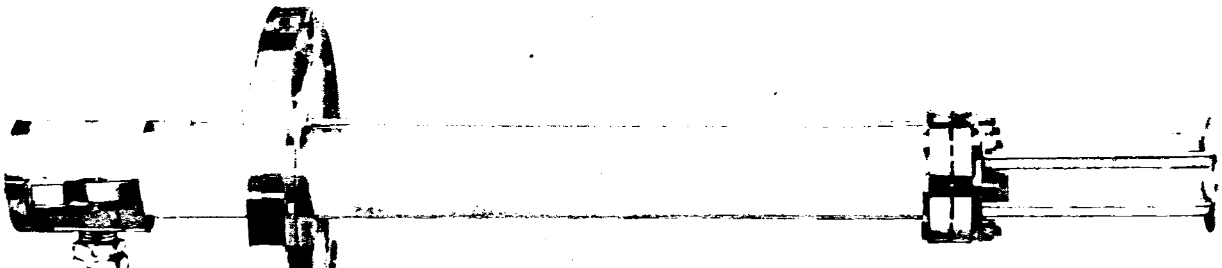
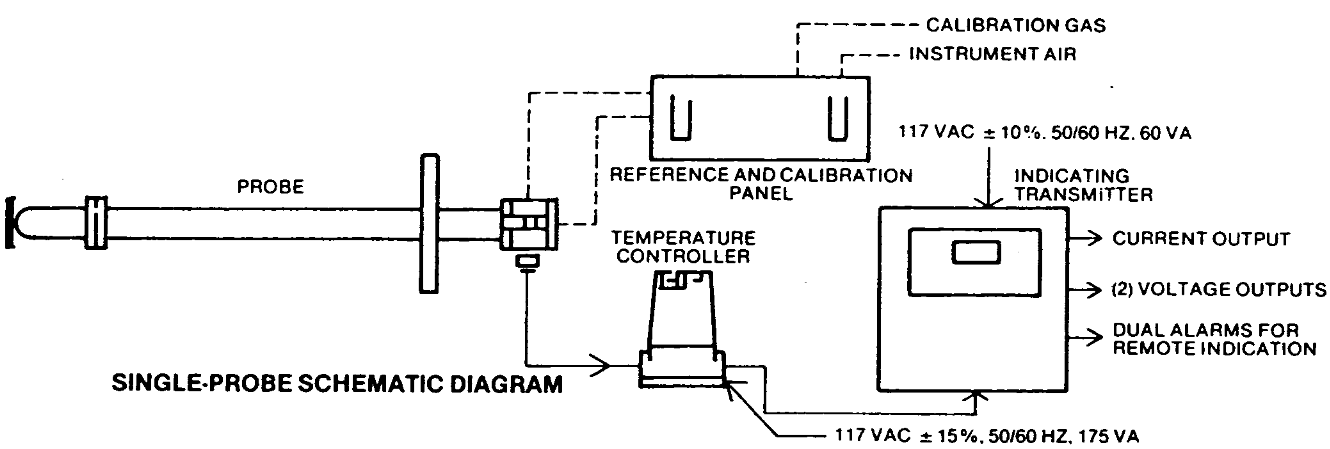


FIGURE 2-93. DIAPHRAGM DRAFT GAGE



The probe which houses the sensor is mounted directly into the stack (in-situ) and utilizes the properties of zirconium oxide for measuring the oxygen content. The process gas is admitted through a protective ceramic filter to the sample side of the sensor and produces an inverse logarithmic DC voltage signal which is sent to the temperature controller.



SINGLE-PROBE SCHEMATIC DIAGRAM

FIGURE 2-94. ZIRCONIUM OXIDE OXYGEN ANALYZER

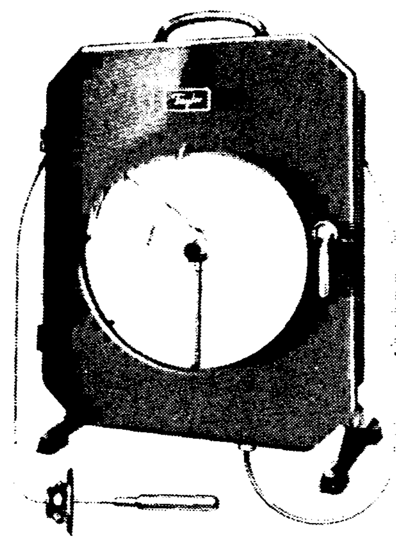


FIGURE 2-95. RECORDING THERMOMETER

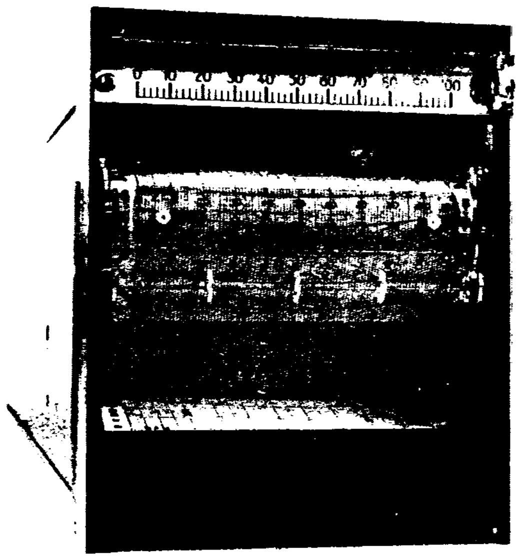


FIGURE 2-96. STRIP CHART RECORDER

76. Others are remotely mounted and receive an electronic or pneumatic signal from the instrumentation element. A typical strip chart type recorder is illustrated in figure 2-96. This particular model can record up to three separate process variables on a 4-inch-wide strip chart, while other models may record up to 20 variables. Both strip charts and circular charts are in typical use in Army Boiler Plants and generally record two to four variables.

2-29. WATER TREATMENT CONTROL.

Instrumentation controls for water treatment systems are discussed in chapter 4.

SECTION V. POLLUTION CONTROL EQUIPMENT

2-30. POLLUTION REGULATIONS.

Control of pollutants from the combustion of fossil fuels in central boiler plants may be required. Boiler plant emission regulations are issued by Federal, state, and local environmental agencies, with the most stringent regulation usually being imposed. Two general types of regulations exist: point source regulations and ambient arir quality standards.

a. Point Source Regulations. Point source regulations place limits upon the quantity of a pollutant which may be emitted from any stack, regardless of its relationship to local air quality. These regulations should be considered to be the minimum regulations, and, if applicabled, must always be met. Typical point source emission levels for the commonly regulated hhpollutants are listed in table 2-1. In most cases, some or all of these regulations will be inapplicable to Army boilers. Federal regulations do not, at the present, apply to boilers of less than 250 million Btu/hr heat input (approximately 180,000-200,000 pounds of steam/fr). Most state and local agencies also have minimum size limitations.

TABLE 2-1.
TYPICAL POINT SOURCE EMISSION LEVELS FOR VARIOUS POLLUTANTS

		Maximum Allowable Emission	
Poilutant	**Fuel**	**LB-Pollutant/ Million Btu**	**PPM at 3% O_2**
Particulate	All	0.1	N/A
NO_x	N.G.	012	160
		Oil	0.3 230
		Coal	0.7 510
SO_x	Oil	0.8	440
		Coal	1.2 630

b. Ambient Air Quality Standards. Ambient air quality standards may be applicable to any size boiler. These standards require that the emissions from the unit be considered, as they affect the air quality of the surrounding area. Consideration must be given to meteorological effects and other pollution sources in the area in determining allowable emission levels. The emission levels determined under ambient air quality standards may be the same as, more stringent than, or less stringent than the applicable point source regulations for a given boiler plant. The actual determination of the applicable limits usually warrants a separate study by a consultant.

2-31. TYPES OF POLLUTANTS AND CONTROL METHODS.

The pollutants listed in table 2-1 are those that are commonly regulated from Army boilers. Their generation and control are discussed briefly in this section. More detailed information can be found in TM 5-815.

a. Oxides of Nitrogen. NO_x is the generic name for a group of pollutants formed from various combinations of nitrogen and oxygen. The principal form generated by boilers is nitric oxide, NO. NO is formed when the nitroge in the fuel and air reacts at high temperature with oxygen from the air. It can be controlled in existing boilers by careful adjustments and modification to the burners aimed at lowering the peak flame temperatures in the furnace and by minimizing the amount of free oxygen available in the highest temperature combustion zones. New boilers which have been purchased to meet specific NO_x emission regulations will generally have these modifications designed into them. In addition, they will also be designed with larger furnaces and more water-cooled surface in the burner zone to improve heat transfer characteristics and to further reduce the peak combustion temperature attained. Some of the modifications and adjustments which can be implemented are listed in table 2-2, as well as advantages and disadvantages of each and the anticipated reduction in NO_x emissions. Additional information on these NO_x reduction techniques is available in Army Manual TM 5-815. However, since relatively few Army boilers are required to meet NO_x regulations, these topics are not discussed further in this manual.

b. Oxides of Sulfur. The primary oxide of sulfur (SOx) formed by the combustion of fossil fuel is sulfur dioxide or SO_2. SO_2 is formed when sulfur from the fuel combines with oxygen from the air in the high temperature zones of the furnace. In a conventional boiler, essentially all the sulfur that enters with the fuel converts to SO_2. No practica form of combustion modification has been developed to reduce SO_2 generation in the furnace. In order to control